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(NASA-CR-171003) ACOUSTIC ENVIRONMENTAL
ACCURACY REQUIREMENTS FOR RESPONSE
DETERMINATION Final Report (Wyle Labs.,
Inc.) 378 p HC A17/MF A01

CSCI 20A

N84-23234

Unclas

G3/71 13082



research REPORT

WYLE LABORATORIES - RESEARCH STAFF
RESEARCH REPORT WR 83-43

**ACOUSTIC ENVIRONMENTAL
ACCURACY REQUIREMENTS
FOR RESPONSE DETERMINATION**

by

Mark R. Pettitt

A Final Report of
Work Performed Under Contract No. NAS8-33379

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

December 1983

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FOREWORD

This report was prepared by Wyle Laboratories, Scientific Services & Systems Group, for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center. The work was performed under contract NAS8-33379, entitled "Acoustic Environmental Accuracy Requirements for Response Identification." Administration of this study was provided under the technical direction of the System Dynamics Laboratory with Dr. L. Schutzenhofer, Mr. S. Guest, and Mr. T. Nesman serving as technical monitors at various times during the course of the program.

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ABSTRACT

A general purpose computer program was developed for the prediction of vehicle interior noise. This program, named VIN, has both modal and statistical energy analysis capabilities for structural/acoustic interaction analysis. The analytical models and their computer implementation were verified through simple test cases with well-defined experimental results. The model was also applied in a Space Shuttle payload bay launch acoustics prediction study. The computer program will process large and small problems with equal efficiency because all arrays are dynamically sized by program input variables at run time. A data base can be built and easily accessed for design studies. The data base significantly reduces the computational costs of such studies by allowing the reuse of the still-valid calculated parameters of previous iterations. Given accurate structural and acoustic response and exterior acoustic field data, the program will yield reliable results. The problem facing the program user will be the determination of the input data. Except for the most simple cases, finite element or experimental structural data will probably be needed for the modal analysis portion of the program. The acoustic component mode synthesis capability of the program makes the determination of the modal analysis range acoustic response less of a problem. For the SEA model, the estimation of the statistical energy analysis parameters, such as the joint acceptance, is required. The joint acceptance includes or is implicitly coupled with structural mode shape information, structural modal density, and external (and internal) pressure distribution estimation. The combined complexity of these factors usually limit the SEA method to rough design trend studies or a post-test semiempirical modeling role. In any case, the general purpose program VIN provides the framework needed to make use of the full capabilities of both the modal analysis and SEA methods for vehicle interior noise predictions.

Section 1

INTRODUCTION

Throughout their operational life, space vehicle structures and payloads are subject to severe dynamic excitation. This excitation stems primarily from two sources: acoustic noise or fluctuating pressures associated with rocket engine exhaust flow or turbulent boundary layer flow in flight and direct mechanical excitation caused by thrust oscillations, turbomachinery, control thrusters, and so forth. The operational Space Shuttle program brings with it a high launch rate and stringent reliability requirements associated with equipment reusability along with an increase in the sophistication and complexity of the payloads. To ensure the operational integrity of the structure and payloads (as well as crew safety), it is mandatory that the dynamic environments be accurately estimated for use as design criteria and in the establishment of test requirements.

The overall objective of this study was to extend and implement the technology base in the definition of the response environment for aerospace structures, the internal acoustic fields, and the resultant effect on payloads, directed toward the establishment of system reliability. Considerations include the material and geometric characteristics of the internal volume and the influence of other payloads within the volume, the effect of subvolumes and the structural influence of noise feedback. The prediction techniques developed were implemented on a digital computer and optimized to handle geometry changes, source variations, and other pertinent parameters. Both modal analysis and statistical energy analysis techniques are available in the general-purpose, user-oriented computer program for vehicle interior noise (VIN) prediction.

The contents of this report are as follows:

Section 2, Modal Analysis. The discrete modal analytical models and special mathematical techniques used in VIN are presented.

Section 3, Statistical Energy Analysis. The statistical energy analysis model used in VIN is presented.

Section 4, Computer Program. The computer program's organization, structure, capabilities, and limitations are described in detail.

Section 5, Computer Program Verification. The accuracies of the analytical models and computer implementation of the models is established for certain classes of vehicle interior noise problems.

Section 6, Computer Program User's Manual. A section of stand-alone capability. It provides the VIN user with all the information needed to exercise the program.

Section 7, Environmental Prediction. Comparisons of VIN predictions of Space Shuttle internal payload bay acoustic levels to OV101 acoustic test data and actual STS-2 flight data are presented.

Section 8, Summary.

Section 2

MODAL ANALYSIS

A relatively recent state-of-the-art review, entitled "Master Plan for Prediction of Vehicle Interior Noise,"⁽¹⁾ listed over 160 references in its annotated bibliography. Most of the references presented a procedure for noise prediction and/or reported the results of experiment. These noise prediction procedures range from simplistic to unworkable in terms of degree of sophistication and information required for implementation. A thorough study of methodologies indicated that the basic analytical development by E. H. Dowell⁽²⁾ provides the simplest and most versatile modal analysis formulation available for low-to medium-frequency structural/acoustic interaction problems of the enclosed cavity type. The acoustic portion of the model is based on Green's theorem in conjunction with small perturbation acoustical relationships. The structure is represented by standard linear relationships with differential pressure across the structural wall as the driving force. Further derivation of the model, which includes normal mode mathematical techniques, results in a set of two coupled differential equations. This coupling occurs because the internal cavity pressure modifies the driving force on the structure. The technique also includes the effects of mass and damping for both the structure and the sound field. An attractive aspect of the formulation is that the differential equations require only "hardwall" acoustic modes and "in vacuo" structural modes. The following is a complete derivation of the modal analytical model used in VIN beginning with a glossary of terms.

Model Derivation

Glossary of Terms

- A_a = area of the absorbing surface
- A_f = area of flexible boundary
- A_r = area of rigid boundary
- c = speed of sound in fluid medium
- C_{nr} = absorption coupling coefficient
- F_n = N-th "hardwall" acoustic mode shape for cavity

L_{mn} = structural-acoustic coupling term
 M = structural mass per unit area
 M_m = structural generalized mass
 M_n^a = acoustic generalized mass
 N = normal to surface
 p = perturbation pressure
 p^e = external perturbation pressure on cavity wall
 P_n = coefficient to acoustic normal mode expansion
 q_m = generalized displacement
 Q_m^{bl} = generalized external blocked pressure
 Q_m^c = generalized internal cavity pressure
 Q_m^e = generalized external pressure
 t = time
 V = volume of cavity
 w = displacement of cavity wall normal to surface
 ω = frequency
 x_o = position in space (x, y, z)
 Z_a = acoustic impedance of cavity walls
 ψ_m = structural normal mode shape
 ρ = density of fluid medium

Summary of Basic Relations Used in Model Derivation

$$p(x_o, t) = \rho c^2 \sum_N P_n(t) F_n(x_o) / M_n^a$$

$$w(x_o, t) = \sum_M q_m(t) \psi_m(x_o)$$

$$M_n^a = 1/V \int_V F_n^2(x_o) dV$$

$$M_m = \int_{A_f} m \psi_m^2(x_o) dA_f$$

$$C_{nr} = 1/A_a \int_{A_a} F_n(x_o) F_r(x_o) / Z_a(x_o) dA_a$$

$$L_{nm} = 1/A_f \int_{A_f} F_n(x_o) \psi_m(x_o) dA_a$$

$$Q_m^e = - \int_{A_f} p^e(x_o, t) \psi_m(x_o) dA$$

$$P_n = 1/(\rho c^2 V) \int_V p(x_o, t) F_n(x_o) dV$$

2.1 Basic Model Derivation

2.1.1 Time Domain Equations

Representation of the vehicle acoustics begins with the wave equation for small pressure perturbations:

$$\nabla^2 p(x_o, t) - \frac{1}{c^2} \frac{\partial^2 p(x_o, t)}{\partial t^2} = 0 \quad (1)$$

Momentum equation on the flexible boundary:

$$\frac{\partial p(x_o, t)}{\partial N} = -\rho \cdot \frac{\partial^2 w(x_o, t)}{\partial t^2} \quad \text{on } A_f \quad (2)$$

Momentum equation on the rigid boundary:

$$\frac{\partial p(x_o, t)}{\partial N} = 0 \quad \text{on } A_r \quad (3)$$

$w(x_o, t)$ is considered positive outward from the cavity.

The rigid wall normal mode solutions of equation 1:

$$p(x_o, t) = F_n(x_o) \rho^i \omega t; n = 0, 1, 2, 3, \dots, \quad (4)$$

where F_n has the properties:

$$\nabla^2 F_n(x_o) = -(\omega_n^2/c^2) F_n(x_o) \quad (5)$$

$$\frac{\partial F_n(x_o)}{\partial N} = 0 \quad \text{on } A = A_f + A_r \quad (6)$$

$$\begin{aligned} 1/V \int_V F_r(x_o) F_n(x_o) dV &= 0; \quad r \neq n \\ &= M_n^a; \quad r=n \end{aligned} \quad (7)$$

Using Green's identity, which relates the surface integral to the volume integral of a bounded volume, the motion of the boundary can be related to the response of the volume.

$$\begin{aligned} \int_V (p(x_o, t) \nabla^2 F_n(x_o) - F_n(x_o) \nabla^2 p(x_o, t)) dV &= \int_A \left(p(x_o, t) \frac{\partial F_n(x_o)}{\partial N} \right. \\ &\quad \left. - F_n(x_o) \frac{\partial p(x_o, t)}{\partial N} \right) dA \end{aligned} \quad (8)$$

Define

$$P_n(t) \equiv \frac{1}{\rho c^2 V} \int_V p(x_o, t) F_n(x_o) dV \quad (9)$$

$$W_n(t) \equiv 1/A \int_A w(x_o, t) F_n(x_o) dA \quad (10)$$

Break equation 8 into parts:

$$\begin{aligned} \int_V p(x_o, t) \nabla^2 F_n(x_o) dV - \int_V F_n(x_o) \nabla^2 p(x_o, t) dV &= \int_A p(x_o, t) \frac{\partial F_n(x_o)}{\partial N} dA \\ &- \int_A F_n(x_o) \frac{\partial p(x_o, t)}{\partial N} dA \end{aligned} \quad (11)$$

Using equations 1, 2, 5, and 6 in equation 11, one obtains

$$\begin{aligned} \int_V F_n(x_o) \frac{1}{\rho c^2} \frac{\partial^2 p(x_o, t)}{\partial t^2} dV - \int_V \left(p(x_o, t) \frac{\omega_n^2}{\rho c^2} F_n(x_o) \right) dV \\ = \int_A F_n(x_o) \frac{\partial^2 w(x_o, t)}{\partial t^2} dA. \end{aligned} \quad (12)$$

Taking constants out of the integrals:

$$\begin{aligned} \frac{1}{\rho c^2} \int_V F_n(x_o) \frac{\partial^2 p(x_o, t)}{\partial t^2} dV - \frac{\omega_n^2}{\rho c^2} \int_V F_n(x_o) p(x_o, t) dV \\ = \int_A \frac{\partial^2 w(x_o, t)}{\partial t^2} F_n(x_o) dA \end{aligned} \quad (13)$$

Substitute definitions 9 and 10 into 13:

$$\frac{\partial^2 P_n(t)}{\partial t^2} + \omega_n^2 P_n(t) = - \frac{\partial^2 W_n(t)}{\partial t^2} \frac{A_f}{V} \quad (14)$$

An absorbent wall can be accounted for using the point impedance concept:

$$p(x_o, t) = Z_a(x_o) \frac{\partial w(x_o, t)}{\partial t} \quad \text{on } A_a \quad (15)$$

Apply the momentum equation:

$$\frac{\partial p(x_o, t)}{\partial N} = \rho \frac{\partial^2 w(x_o, t)}{\partial t^2} \quad \text{on } A_a \quad (16)$$

From equation 15,

$$\frac{\partial^2 w(x_o, t)}{\partial t^2} = \frac{1}{Z_a} \frac{\partial p(x_o, t)}{\partial t} \quad (17)$$

Substitute equation 17 into 16:

$$\frac{\partial p(x_o, t)}{\partial N} = -\rho \frac{1}{Z_a} \frac{\partial p(x_o, t)}{\partial t} \quad (18)$$

Substitute equation 18 into equation 8, and solve equation 8 as before to obtain

$$\frac{\partial^2 P_n(t)}{\partial t^2} + \frac{A_a}{V} \rho c \sum_r \left(\frac{C_{nr}}{M_r^a} \frac{\partial P_r(t)}{\partial t} \right) + \omega_n^2 P_n(t) = \frac{-A_f}{V} \frac{\partial^2 W_a(t)}{\partial t^2} \quad (19)$$

where

$$C_{nr} = \frac{1}{A_a} \int_{A_a} \frac{F_n(x_o) F_r(x_o)}{Z_a(x_o)} dA_a \quad (20)$$

Finally, from equation 9,

$$p(x_o, t) = \rho c^2 \sum_n \frac{F_n(x_o)}{M_n^a} \cdot P_n(t) \quad (21)$$

The right-hand side of equation 19 can be expressed in normal mode form; let the wall deflection be expressed in series form:

$$w(x_o, t) = \sum_m q_m(t) \psi_m(x_o) \quad (22)$$

The modal functions $\psi_m(x_o)$ are defined over the region A_f with properties determined by the structure.

Recall equation 10:

$$W_n(t) = 1/A_f \int_{A_f} w(x_o, t) F_n(x_o) dA_f$$

Substitute equation 22 into equation 10 to obtain

$$W_n(t) = 1/A_f \int_{A_f} \sum_m q_m(t) \psi_m(x_o) F_n(x_o) dA_f \quad (23)$$

Extract the time term from the integrals:

$$W_n(t) = 1/A_f \sum_m q_m(t) \int_{A_f} \psi_m(x_o) F_n(x_o) dA_f \quad (24)$$

Define

$$L_{nm} = 1/A_f \int_{A_f} \psi_m(x_o) F_n(x_o) dA_f \quad (25)$$

Then

$$W_n(t) = \sum_m L_{nm} q_m(t) \quad (26)$$

and

$$\frac{\partial^2 W_n(t)}{\partial t^2} = \sum_m L_{nm} \frac{\partial^2 q_m(t)}{\partial t^2} \quad (27)$$

Substitute equation 27 into 19:

$$\begin{aligned} \frac{\partial^2 p_n(t)}{\partial t^2} + \frac{A_a}{V} \rho c^2 \sum_r \frac{C_{nr}}{M_r^a} \frac{\partial p_r(t)}{\partial t} + \omega_n^2 p_n(t) \\ = \frac{-A_f}{V} \sum_m L_{nm} \frac{\partial^2 q_m(t)}{\partial t^2} \end{aligned} \quad (28)$$

Equation 28 is a differential equation in time only and represents the acoustics of a volume bounded by a structure. The structure can be represented by a linear partial differential equation of the form

$$S w(x_o, t) + F_d + M \frac{\partial^2 w(x_o, t)}{\partial t^2} = p(x_o, t) - p^e(x_o, t) \quad (29)$$

S = linear differential operator representing structural stiffness.

F_d = damping force; a common model is the viscous damper.

$$F_d = C \frac{\partial w(x_o, t)}{\partial t}$$

$M \frac{\partial^2 w(x_o, t)}{\partial t^2}$ = structural inertial force per unit area.

$p(x_o, t)$ = internal cavity pressure.

$p^e(x_o, t)$ = external cavity pressure.

For simplicity, one can assume the structural modes, ω_m , are normal in vacuo modes satisfying the eigenvalue problem:

$$S \psi_m(x_o) - M \psi_m(x_o) \omega_m^2 = 0, \quad (30)$$

with

$$\begin{aligned} \int_{A_f} M \psi_m(x_o) \psi_r(x_o) dA &= 0 \quad ; \quad m \neq r \\ &= M_m \quad ; \quad m = r. \end{aligned} \quad (31)$$

ω_m is the m-th structural natural frequency and ψ_m its associated normal mode.

Substitute equation 22 into 29:

$$S \left(\sum_m q_m(t) \psi_m(x_o) \right) + C \sum_m \psi_m(x_o) \frac{\partial q_m(t)}{\partial t} + M \sum_m \psi_m(x_o) \frac{\partial^2 q_m(t)}{\partial t^2} = p(x_o, t) - p^e(x_o, t) \quad (32)$$

Rearrange

$$\sum_m \left(S q_m(t) + C \frac{\partial q_m(t)}{\partial t} + M \frac{\partial^2 q_m(t)}{\partial t^2} \right) \psi_m(x_o) = p(x_o, t) - p^e(x_o, t) \quad (33)$$

Recall from equation 30 that

$$S = M \omega_m^2. \quad (34)$$

Substitute into equation 33:

$$\sum_m M \left(\omega_m^2 q_m(t) + \frac{C}{M} \frac{\partial q_m(t)}{\partial t} + \frac{\partial^2 q_m(t)}{\partial t^2} \right) \psi_m(x_o) = p(x_o, t) - p^e(x_o, t) \quad (35)$$

Multiply through by $\psi_m(x_o)$ and integrate over the area A_f . Apply orthogonality relations; obtain:

$$\left(\omega_m^2 q_m(t) + \frac{C}{M} \frac{\partial q_m(t)}{\partial t} + \frac{\partial^2 q_m(t)}{\partial t^2} \right) M_m = Q_m(t) + Q_m^e(t) \quad (36)$$

where

$$Q_m(t) = \int_{A_f} p(x_o, t) \psi_m(x_o) dA_f \quad (37)$$

$$Q_m^e(t) = - \int_{A_f} p^e(x_o, t) \psi_m(x_o) dA_f$$

Substitute equation 21 into equation 37 for $Q_m(t)$:

$$Q_m(t) = \int_{A_f} \rho c^2 \sum_n \frac{F_n(x_o)}{M_n^a} P_n(t) \psi_m(x_o) dA_f \quad (38)$$

$$Q_m(t) = \sum_n \frac{\rho c^2}{M_n^a} P_n(t) \int_{A_f} F_n(x_o) \psi_m(x_o) dA_f \quad (39)$$

Substituting equation 25 into equation 39:

$$Q_m(t) = \rho c^2 A_f \sum_n \frac{P_n(t)}{M_n^a} L_{nm} \quad (40)$$

Substitute equation 40 into equation 36 to obtain the desired form for the structural equation:

$$\begin{aligned} \left(\omega_m^2 q_m(t) + \frac{C}{M} \frac{\partial q_m(t)}{\partial t} + \frac{\partial^2 q_m(t)}{\partial t^2} \right) M_m \\ = \rho c^2 A_f \sum_n \frac{P_n(t) L_{nm}}{M_n^a} + Q_m^e(t) \end{aligned} \quad (41)$$

In summary, the vehicle interior noise problem can be modeled by a set of coupled differential equations, one describing the acoustic response (equation 28) and one representing the structural response (equation 41).

Acoustic Equation:

$$\begin{aligned} \frac{\partial^2 P_n(t)}{\partial t^2} + \frac{A_a \rho c^2}{V} \sum_r \frac{C_{nr}}{M_r^a} \frac{\partial P_r(t)}{\partial t} + \omega_n^2 P_n(t) \\ = \frac{-A_f}{V} \sum_m L_{mn} \frac{\partial q_m(t)}{\partial t^2} \end{aligned}$$

Structural Equation:

$$M_m \left(\frac{\partial^2 q_m(t)}{\partial t^2} + \frac{C}{M} \frac{\partial q_m(t)}{\partial t} + \omega_m^2 q_m(t) \right) = \rho c^2 A_p \sum_n \frac{P_n(t) L_{nm}}{M_n^a} + Q_m^e(t)$$

Given some external pressure field or point force on the structure $Q_m^e(t)$, the equations can be solved by any standard method to obtain $P_n(t)$. With $P_n(t)$, the internal pressure at a point or the average internal pressure can be calculated. Recall equation 21:

$$p(x_o, t) = \rho c^2 \sum_n \frac{P_n(t) F_n(x_o)}{M_n^a}$$

The space-averaged pressure squared over the vehicle structure at time, t , is calculated by

$$\begin{aligned} \langle p^2(x_o, t) \rangle &= \frac{1}{V} \int_V p^2(x_o, t) dV \\ &= \frac{1}{V} \int_V \rho c^2 \sum_n \frac{P_n(t) F_n(x_o)}{M_n^a} \rho c^2 \sum_{n'} \frac{P_{n'}^*(t) F_{n'}(x_o)}{M_{n'}^a} dV \\ &= \rho^2 c^4 \sum_n \sum_{n'} \frac{P_n(t) P_{n'}^*(t)}{M_n^a M_{n'}^a} \frac{1}{V} \int_V F_n(x_o) F_{n'}(x_o) dV \end{aligned}$$

Due to orthogonality,

$$\int_V F_n(x_o) F_{n'}(x_o) dV = 0 \text{ for } n \neq n'.$$

Hence, the space-averaged pressure squared over the volume can be calculated by

$$\langle p^2(x_0, t) \rangle_{\text{volume}} = \rho^2 c^4 \sum_n \frac{P_n^2(t)}{M_n^a} \quad (42)$$

2.1.2 Frequency Domain Equations

Equations in the frequency domain can also be obtained. Let

$$P_n(t) = \int_{-\infty}^{\infty} \bar{P}_n(\omega) e^{-i\omega t} d\omega \quad (43)$$

$$\frac{\partial P_n(t)}{\partial t} = \int_{-\infty}^{\infty} -i\omega \bar{P}_n(\omega) e^{-i\omega t} d\omega$$

$$\frac{\partial^2 P_n(t)}{\partial t^2} = \int_{-\infty}^{\infty} -\omega^2 \bar{P}_n(\omega) e^{-i\omega t} d\omega$$

and

$$q_m(t) = \int_{-\infty}^{\infty} \bar{q}_m(\omega) e^{-i\omega t} d\omega \quad (44)$$

$$\frac{\partial q_m(t)}{\partial t} = \int_{-\infty}^{\infty} -i\omega \bar{q}_m(\omega) e^{-i\omega t} d\omega$$

$$\frac{\partial^2 q_m(t)}{\partial t^2} = \int_{-\infty}^{\infty} -\omega^2 \bar{q}_m(\omega) e^{-i\omega t} d\omega$$

And

$$\begin{aligned} Q_m^e(t) &= \int_{-\infty}^{\infty} \int_{A_f} \bar{p}^e(x_o, \omega) \psi_m(x_o) dA_f e^{-i\omega t} d\omega \\ &= \int_{-\infty}^{\infty} \bar{Q}_m^{bl}(\omega) e^{-i\omega t} d\omega \end{aligned} \quad (45)$$

Substitute these relations into the time domain differential equations:

$$\begin{aligned} \int_{-\infty}^{\infty} \left(\left(-\omega^2 - \frac{A_a \rho c^2}{V} \sum_r \frac{C_{nr}}{M_r^a} \omega i + \omega_n^2 \right) \bar{P}_n(\omega) \right. \\ \left. - \sum_m \frac{A_f}{V} L_{nm} \omega^2 \bar{q}_m(\omega) \right) e^{-i\omega t} d\omega = 0 \end{aligned} \quad (46)$$

and

$$\begin{aligned} \int_{-\infty}^{\infty} \left(M_m \left(-\omega^2 - \frac{C}{M} \omega i + \omega_m^2 \right) \bar{q}_m(\omega) \right. \\ \left. - \left(\rho c^2 A_f \sum_n \frac{L_{nm}}{M_n^a} \omega i \right) \bar{P}_n(\omega) - \bar{Q}_m^{bl}(\omega) \right) e^{-i\omega t} d\omega = 0 \end{aligned} \quad (47)$$

If equations 45 and 46 are to hold, the integrands must be equal to zero. Hence,

Acoustic frequency domain equation:

$$\left(-\omega^2 - \frac{A_a \rho c^2}{V} \sum_r \frac{C_{nr}}{M_r^a} \omega i + \omega_n^2 \right) \bar{P}_n(\omega) = \sum_m \frac{A_f}{V} L_{nm} \omega^2 \bar{q}_m(\omega) \quad (48)$$

Structural frequency domain equation:

$$M_m \left(-\omega^2 - \frac{C}{M} \omega i + \omega_m^2 \right) \bar{q}_m(\omega) - \rho c^2 A_f \sum_n \frac{L_{nm}}{M_n^a} \omega i \bar{P}_n(\omega) = \bar{Q}_m^{bl}(\omega) \quad (49)$$

If one is interested in the acoustic pressure inside the structure, equations 48 and 49 can be combined to eliminate $\bar{q}_m(\omega)$. From equation 48:

$$\bar{P}_n(\omega) = \left(\sum_m \frac{A_f}{V} L_{nm} \omega^2 \bar{q}_m(\omega) \right) / \left(-\omega^2 - \sum_r 2\zeta_{nr}^a \omega_n^a \omega_i + \omega_n^{a^2} \right) \quad (50)$$

where

$$2\zeta_{nr}^a \omega_n = \frac{A_a}{V} \rho c^2 \frac{C_{nr}}{M_n^a}$$

From equation 49:

$$\bar{q}_m(\omega) = \frac{\left(\bar{Q}_m^{bl} + \rho c^2 A_f \sum_n \frac{L_{nn}}{M_n^a} \omega_i \bar{P}_n(\omega) \right)}{M_m \left(-\omega^2 - 2\zeta_m \omega_m \omega_i + \omega_m^2 \right)} \quad (51)$$

where

$$2\zeta_m \omega_m = \frac{C}{M} \quad \text{Viscous damping model} \quad (52)$$

$$\bar{Q}_m^{bl} = \text{Generalized force (understood function of } \omega)$$

Substitute equation 51 into 50 and changing the summation index n in equation 51 to s to avoid confusion with the index in equation 50.

$$\bar{P}_n(\omega) = \sum_m \left(\frac{A_f}{V} L_{nm} \omega^2 \left(\bar{Q}_m^{bl} + \rho c^2 A_f \sum_s \frac{L_{sm}}{M_s^a} \omega_i \bar{P}_s(\omega) \right) \right) / \left(M_m \left(-\omega^2 - 2\zeta_m \omega_m \omega_i + \omega_m^2 \right) \right) / \left(-\omega^2 - \sum_r 2\zeta_{nr}^a \omega_n^a \omega_i + \omega_n^{a^2} \right) \quad (53)$$

To shorten the equation, define:

$$\Gamma_n(\omega) \equiv \left(-\omega^2 - \sum_r 2\zeta_{nr} \omega_n \omega_i + \omega_n^2 \right) \quad (54)$$

$$\tau_m(\omega) \equiv M_m \left(-\omega^2 - 2\zeta_m \omega_m \omega_i + \omega_m^2 \right)$$

Equation 53 becomes

$$\begin{aligned} \bar{P}_n(\omega) = \sum_m \left(\frac{A_f}{V} L_{nm} \omega^2 \left(\bar{Q}_m^{bl} \right. \right. \\ \left. \left. + \rho c^2 A_f \sum_s \frac{L_{sm}}{M_s^a} \omega_i \bar{P}_s(\omega) \right) / \tau_m(\omega) \right) / \Gamma_n(\omega) \end{aligned} \quad (55)$$

Solution of this equation involves a set of "n" equations and "n" unknowns. The coupled nature of the solution is, as previously discussed, caused by the effect of the internal cavity pressure on the structural response of the cavity wall. Equation 55 can be made more clear by the following expansion:

$$\begin{aligned} \bar{P}_n(\omega) = \sum_m \left[\frac{A_f L_{nm} \omega^2}{\tau_m(\omega)} \left(\bar{Q}_m^{bl} + \rho c^2 A_f \frac{L_{om}}{M_o^a} \omega_i \bar{P}_o(\omega) \right. \right. \\ \left. \left. + \rho c^2 A_f \frac{L_{1m}}{M_1^a} \omega_i \bar{P}_1(\omega) + \rho c^2 A_f \frac{L_{2m}}{M_2^a} \omega_i \bar{P}_2(\omega) \right. \right. \\ \left. \left. + \dots + \rho c^2 A_f \frac{L_{nm}}{M_n^a} \omega_i \bar{P}_n(\omega) \right. \right. \\ \left. \left. + \dots + \rho c^2 A_f \frac{L_{sm}}{M_s^a} \omega_i \bar{P}_s(\omega) \right) \right] / \Gamma_n(\omega) \end{aligned} \quad (56)$$

Solve for $\bar{P}_n(\omega)$:

$$\begin{aligned} \bar{P}_n(\omega) \cdot \Gamma_n(\omega) &= \sum_m \left[\frac{A_f}{V} \frac{L_{nm} \omega^2}{\Gamma_m(\omega)} \left(\bar{Q}_m^{bl} + \rho c^2 A_f \sum_{s \neq n} \frac{L_{sm}}{M_s^a} \omega i \bar{P}_s(\omega) \right) \right] \\ &+ \sum_m \left[\frac{A_f}{V} \frac{L_{nm}}{\Gamma_m(\omega)} \rho c^2 A_f \frac{L_{nm}}{M_n^a} \omega i \bar{P}_n(\omega) \right] \end{aligned} \quad (57)$$

$$\begin{aligned} \bar{P}_n(\omega) \cdot \Gamma_n(\omega) &= \sum_m \left[\frac{A_f}{V} \frac{L_{nm} \omega^2}{\Gamma_m(\omega)} \rho c^2 A_f \frac{L_{nm}}{M_n^a} \omega i \right] \\ &= \sum_m \left[\frac{A_f}{V} \frac{L_{nm} \omega^2}{\Gamma_m(\omega)} \left(\bar{Q}_m^{bl} + \rho c^2 A_f \sum_{s \neq n} \frac{L_{sm}}{M_s^a} \omega i \bar{P}_s(\omega) \right) \right] \end{aligned} \quad (58)$$

And finally,

$$\bar{P}_n(\omega) = \frac{\sum_m \left[\frac{A_f}{V} \frac{L_{nm} \omega^2}{\Gamma_m(\omega)} \left(\bar{Q}_m^{bl} + \rho c^2 A_f \sum_{s \neq n} \frac{L_{sm}}{M_s^a} \omega i \bar{P}_s(\omega) \right) \right]}{\left[\Gamma_n(\omega) - \sum_m \left[\frac{A_f}{V} \frac{L_{nm} \omega^2}{\Gamma_m(\omega)} \rho c^2 A_f \frac{L_{nm}}{M_n^a} \omega i \right] \right]} \quad (59)$$

$$\bar{P}_n(\omega) = \frac{\sum_m \left[\frac{A_f}{V} \frac{L_{nm} \omega^2}{\Gamma_m(\omega) \Gamma_n(\omega)} \left(\bar{Q}_m^{bl} + \rho c^2 A_f \sum_{s \neq n} \frac{L_{sm}}{M_s^a} \omega i \bar{P}_s(\omega) \right) \right]}{\left[1 - \sum_m \frac{A_f L_{nm} \omega^2}{\Gamma_m(\omega) \Gamma_n(\omega)} \frac{\rho c^2 A_f L_{nm} \omega i}{M_n^a} \right]} \quad (60)$$

Let

$$I_{nm} = \frac{A_f L_{nm} \omega^2}{V \tau_m(\omega) \Gamma_n(\omega)} \quad (60a)$$

$$K_{sm} = \rho c^2 A_f \frac{L_{sm}}{M_s^a} \omega i$$

$$K_{nm} = \rho c^2 A_f \frac{L_{nm}}{M_n^a} \omega i$$

Hence,

$$\bar{P}_n(\omega) = \frac{\left[\sum_m I_{nm} \left(\bar{Q}_m^{bl} + \sum_{s \neq n} K_{sm} \bar{P}_s(\omega) \right) \right]}{\left(1 - \sum_m I_{nm} K_{nm} \right)} \quad (61)$$

Equation 61 can be used to generate the set of simultaneous frequency domain equations required to solve closed cavity problems in which the effect of the internal sound field on the motion of the structure is significant.

When the acoustoelastic coupling is negligible, the problem solution becomes much simpler. The acoustic equation and the structural equation are independent. Equation 51 becomes

$$\bar{q}_m(\omega) = \frac{(\bar{Q}_m^{bl})}{\tau_m(\omega)} \quad (62)$$

Substitute equation 62 into equation 51:

$$\bar{P}_n(\omega) = \sum_m \frac{A_f}{V} \frac{L_{nm} \omega^2 \bar{Q}_m^{bl}}{\tau_m(\omega) \Gamma_n(\omega)} \quad (63)$$

Using the definition of I_{nm} (equation 60),

$$\bar{P}_n(\omega) = \sum_m I_{nm} \bar{Q}_m^{bl} \quad (64)$$

Hence, the solution for each mode "n" consists of a single equation when the effect of the cavity pressure on the wall motion can be neglected. In either case, once $\bar{P}_n(\omega)$ has been found, the pressure can be calculated.

$$p(x_o, \omega) = \rho c^2 \sum_n \frac{\bar{P}_n(\omega) F_n(x_o)}{M_n^a} \quad (65)$$

Equation 65 yields the pressure at a point and at a single frequency. Other quantities of interest are the space-averaged pressure squared at a frequency and the space-averaged, band-limited pressure squared. The mean square pressure is

$$p^2(x_o, \omega) = p(x_o, \omega) p^*(x_o, \omega) / 2 \quad (66)$$

Recall equation 65:

$$p(x_o, \omega) = \rho c^2 \sum_n \frac{\bar{P}_n(\omega) F_n(x_o)}{M_n^a}$$

Then

$$p^*(x_o, \omega) = \rho c^2 \sum_{n'} \frac{\bar{P}_{n'}^*(\omega) F_{n'}(x_o)}{M_{n'}^a}$$

Hence,

$$p^2(x_o, \omega) = \frac{1}{2} \rho^2 c^4 \sum_n \sum_{n'} \frac{\bar{P}_n(\omega) \bar{P}_{n'}^*(\omega)}{M_n^a M_{n'}^a} F_n(x_o) F_{n'}(x_o) \quad (67)$$

$$\text{Space average } \langle p^2(x_o, \omega) \rangle = 1/V \int_V p^2(x_o, \omega) dV \quad (68)$$

$$\langle p^2(x_o, \omega) \rangle = \sum_n \sum_{n'} \frac{1}{2} \rho^2 c^4 \frac{P_n(\omega) P_{n'}^*(\omega)}{M_n^a M_{n'}^a} \left(\frac{1}{V} \int_V F_n(x_o) F_{n'}(x_o) dV \right) \quad (69)$$

Because of the orthogonality of the normal modes $F_n(x_o)$, equation 69 reduces to

$$\langle p^2(x_o, \omega) \rangle = \sum_n \frac{\rho^2 c^4}{2} \frac{P_n(\omega) P_n^*(\omega)}{M_n^a} \quad (70)$$

To obtain space-averaged, band-limited pressure squared, simply apply integration techniques over the band of interest.

$$\langle p^2(x_o, \omega) \rangle_{\text{band}} = \int_{\text{band}} \left(\sum_n \frac{1}{2} \rho^2 c^4 \frac{\bar{P}_n(\omega) \bar{P}_n^*(\omega)}{M_n^a} \right) d\omega \quad (71)$$

In the case of a deterministic external pressure field, equations 65, 70, and 71 can be solved. However, if the external pressure field must be considered random, further derivation is required to adapt the equations to accept external pressure field information in that form. One method of developing probability descriptions of random variables is through the use of the expected value:

$$E[\underline{x}] = \int_{-\infty}^{\infty} \underline{x} f_{\underline{x}}(\underline{x}) d\underline{x}$$

where \underline{x} - denotes a random variable

$f_{\underline{x}}(\underline{x})$ - density of the random variable \underline{x}

In the case of Fourier transformed data, the random variables are functions of ω based on a sample length T. Recall equation 70 (the space-averaged pressure squared).

$$\langle p^2(x_o, \omega) \rangle = \sum_n \frac{1}{2} \rho^2 c^4 \frac{\bar{P}_n^*(\omega) \bar{P}_n(\omega)}{M_n^a}$$

Take the expected value of both sides:

$$E \left[\langle p^2(x_o, \omega) \rangle \right] = \sum_n \frac{1}{2} \frac{\rho^2 c^4}{M_n^a} E \left[\bar{P}_n^*(\omega) \bar{P}_n(\omega) \right] \quad (72)$$

Let

$$\begin{aligned} S_p(\omega) &= E \left[\langle p^2(x_o, \omega) \rangle \right] \\ S_{\bar{P}_n}(\omega) &= E \left[\bar{P}_n^*(\omega) \bar{P}_n(\omega) \right] \end{aligned} \quad (73)$$

When the effect of the internal pressure on the cavity structure is negligible, $S_{\bar{P}_n}(\omega)$ can be calculated.

$$\bar{P}_n(\omega) = \sum_m I_{nm} \int_A \bar{p}^e(x'_o, \omega) \psi_m(x_o) dA \quad (74)$$

$$\bar{P}_n^*(\omega) = \sum_s I_{ns}^* \int_{A'} \bar{p}^{e*}(x'_o, \omega) \psi_s(x'_o) dA' \quad (75)$$

Then

$$\bar{P}_n^*(\omega) \bar{P}_n(\omega) = \sum_s \sum_m I_{ns}^* I_{nm} \int_{A'} \int_A p^{e*}(x'_o, \omega) p^e(x_o, \omega) \psi_s(x'_o) \psi_m(x_o) dA dA' \quad (76)$$

Take the expected value of equation 76

$$E \left[\bar{P}_n^*(\omega) \bar{P}_n(\omega) \right] = \sum_s \sum_m I_{ns}^* I_{nm} \int_{A'} \int_A E \left[p^{e*}(x'_o, \omega) p^e(x_o, \omega) \right] \psi_s(x'_o) \psi_m(x_o) dA dA' \quad (77)$$

Define the joint acceptance

$$J_{ms}^2(\omega) = \frac{1}{S_{pbl}(\omega) A^2} \cdot \int_A \int_{A'} S_{pbl}(x_o | x'_o, \omega) \psi_s(x_o) \psi_m(x'_o) dA' dA \quad (78)$$

$S_{pbl}(\omega)$ - Blocked pressure power spectral density at reference point or averaged over the surface.

$S_{pbl}(x_o | x_o', \omega)$ - Blocked pressure cross-power spectral density.

Substitute into equation 77

$$\begin{aligned} E \left[P_n^*(\omega) P_n(\omega) \right] &= \sum_s \sum_m I_{ns}^* I_{nm} A^2 S_{pbl}(\omega) J_{ms}^2(\omega) \cdot 2 \\ &= 2 A^2 S_{pbl}(\omega) \left(\sum_s \sum_m I_{ns}^* I_{nm} J_{ms}^2(\omega) \right) \end{aligned} \quad (79)$$

Substitute equation 79 into equation 72

$$E \left[\langle p^2(x_o, \omega) \rangle \right] = \sum_n \frac{\rho_c^2 4}{M_n^a} \cdot A^2 S_{pbl}(\omega) \cdot \left(\sum_s \sum_m I_{ns}^* I_{nm} J_{ms}^2(\omega) \right) \quad (80)$$

In many cases, $J_{ms} \approx 0$ when $m \neq s$. This approximation is valid if the structural damping is light and the correlation length of the external pressure field is small. The approximation simply asserts that the cross coupling between modes of the structure is negligible. With this generally valid assumption, the space-averaged, band-averaged pressure becomes

$$S_p(\omega) = \sum_n \frac{\rho_c^2 4}{M_n^a} A^2 S_{pbl}(\omega) \sum_m |I_{nm}|^2 J_{mm}^2(\omega) \quad (81)$$

Equation 81 is used to calculate the expected value of the space-averaged pressure squared at a given frequency when the effect of internal cavity pressure on the motion of the cavity wall is negligible. If the coupling is important, a solvable random formulation has not been obtained. In such cases, a representative time history of the external excitation can be synthesized and the deterministic solution found.

The band-limited, space-averaged pressure squared can be analytically calculated.

$$\int_{\omega_1}^{\omega_2} S_p(\omega) d\omega = A^2 \rho^2 c^4 \sum_n \frac{1}{M_n^a} \cdot \int_{\omega_1}^{\omega_2} S_{pbl}(\omega) \sum_m |I_{nm}|^2 J_{mn}^2(\omega) d\omega$$

Assuming $S_{pbl}(\omega)$ and $J_{mn}^2(\omega)$ are constant over the band,

$$\int_{\omega_1}^{\omega_2} S_p(\omega) d\omega = A^2 \rho^2 c^4 \sum_n \frac{1}{M_n^a} \cdot S_{pbl}(\omega_c) \sum_m J_{mn}^2(\omega_c) \int_{\omega_1}^{\omega_2} |I_{nm}|^2 d\omega \quad (82)$$

where ω_c = center frequency of the band.

The integral over frequency in equation 82 can be analytically evaluated through integration by parts. For the sake of brevity, the long and tedious integration is not given here. If the exterior pressure is expressed in terms of band-limited mean square pressure, replace $S_{pbl}(\omega_c)$ with the band level, BS_{pbl} , divided by the bandwidth.

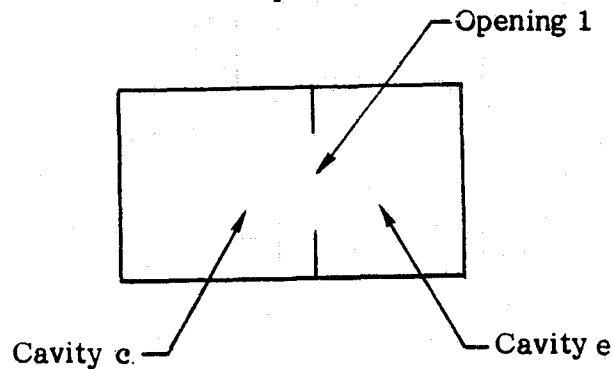
2.2 Peripheral Developments to the Modal Analysis Model

Various extensions to the basic model can be made to increase the versatility of a computer program implementing the model. In this section, these developments are presented and discussed.

2.2.1 Acoustic Component Mode Synthesis

If the acoustic normal modes of a cavity shape are not known, they can be found through a process called "component mode synthesis." In this process, the complex cavity is approximated by several smaller cavities of known modal characteristics. By forcing the pressures to be equal at the openings between the subcavities, a solution for

the normal modes of the complex cavity can be obtained. The following is a sample derivation for the simple case of two cavities connected by one opening. It should be noted that the "opening" could be a structural panel.



The structural equation for the opening between the cavities can be written:

$$Sw(x_o, t) + C \frac{\partial w(x_o, t)}{\partial t} + m \frac{\partial^2 w(x_o, t)}{\partial t^2} = p^c(x_o, t) - p^e(x_o, t) \quad (83)$$

Define the normal modes as before.

$$\begin{aligned} w(x_o, t) &= \sum_m q_m(t) \psi_m(x_o) \\ S\psi_m - M\psi_m \omega_m^2 &= 0 \\ \int_A M\psi_m(x_o)\psi_r(x_o)dA &= M_m \quad m=r \\ &= 0 \quad m \neq r \end{aligned} \quad (84)$$

Substitute equations of 84 into 83:

$$\sum_m M \left(\frac{\partial^2 q_m(t)}{\partial t^2} + C \frac{\partial q_m(t)}{\partial t} + \omega_m^2 q_m(t) \right) \psi_m(x_o) = p^c(x_o, t) - p^e(x_o, t) \quad (85)$$

Recall that

$$p(x_o, t) = \rho c^2 \sum_n P_n(t) \frac{F_n(x_o)}{M_n^a}$$

Hence,

$$\begin{aligned} \sum_m M \left(\frac{\partial^2 q_m(t)}{\partial t^2} + C \frac{\partial q_m(t)}{\partial t} + \omega_m^2 q_m(t) \right) \psi_m(x_o) \\ = \rho c^2 \sum_n P_n^c(t) \frac{F_n^c(x_o)}{M_n a_c} - \rho c^2 \sum_n P_n^e(t) \frac{F_n^e(x_o)}{M_n a_e} \end{aligned} \quad (86)$$

Multiply through by $\psi_f(x_o)$ and integrate over A_f :

$$\begin{aligned} \sum_m \left(\frac{\partial^2 q_m(t)}{\partial t^2} + C \frac{\partial q_m(t)}{\partial t} + \omega_m^2 q_m(t) \right) M_m \\ = \int_{A_f} \rho c^2 \sum_n \frac{P_n^c(t) F_n^c(x_o)}{M_n a_c} \psi_m(x_o) dA_f \\ - \int_{A_f} \rho c^2 \sum_n \frac{P_n^e(t) F_n^e(x_o)}{M_n a_e} \psi_m(x_o) dA \end{aligned} \quad (87)$$

Using the definition of equation 25 in equation 87,

$$\begin{aligned} \sum_m \left(\frac{\partial^2 q_m(t)}{\partial t^2} + C \frac{\partial q_m(t)}{\partial t} + \omega_m^2 q_m(t) \right) M_m \\ = \rho c^2 A_f \sum_n \frac{P_n^c(t) L_{nm}^c}{M_n a_c} \\ - \rho c^2 A_f \sum_n \frac{P_n^e(t) L_{nm}^e}{M_n a_e} \end{aligned} \quad (88)$$

In a multiple cavity problem with more than one opening, an equation like 88 is written for each opening.

The hard wall acoustic equations for each cavity are

$$\frac{\partial^2 p_n^c(t)}{\partial t^2} + \omega_n^2 p_n^c(t) = -\frac{A_f}{V_c} \sum_m \frac{\partial^2 q_m(t)}{\partial t^2} L_{nm}^c \quad (89)$$

$$\frac{\partial^2 p_n^e(t)}{\partial t^2} + \omega_n^2 p_n^e(t) = \frac{A_f}{V_e} \sum_m \frac{\partial^2 q_m(t)}{\partial t^2} L_{nm}^e \quad (90)$$

In a system of more than two cavities, one equation must be written for each cavity in the system. The right-hand side is the forcing function of the cavity and represents the motion of the opening to the cavity.

Shifting to the frequency domain and making the standard substitutions,

$$M_m \left(-\omega^2 + 2\zeta_m \omega_m \omega i + \omega_m^2 \right) \bar{q}_m(\omega) = \rho c^2 A_f \sum_n \frac{\bar{p}_n^c(\omega) L_{nm}^c}{M_n^c} - \rho c^2 A_f \sum_n \frac{\bar{p}_n^e(\omega) L_{nm}^e}{M_n^e} \quad (91)$$

$$\left(-\omega^2 + \omega_n^2 \right) \bar{p}_n^c(\omega) = -\frac{A_f}{V_c} \sum_m \left(-\omega^2 \bar{q}_m(\omega) L_{nm}^c \right) \quad (92)$$

$$\left(-\omega^2 + \omega_n^2 \right) \bar{p}_n^e(\omega) = +\frac{A_f}{V_e} \sum_m \left(-\omega^2 \bar{q}_m(\omega) L_{nm}^e \right) \quad (93)$$

In principle, any number of cavities and openings could be accommodated. The set of equations includes one equation for each opening and one equation for each cavity. The number of terms on the RHS of equations 92 and 93 depend on the number of openings into the cavity.

In the case of a pure opening (i.e., no wall), the result can be simplified because M_m goes to zero:

$$0 = A_f \sum_n \frac{\bar{P}_n^c(\omega) L_{nr}^c}{M_n^c} - A_f \sum_n \frac{\bar{P}_n^e(\omega) L_{nr}^e}{M_n^e} \quad (94)$$

$$\bar{P}_n^c(\omega) = - \frac{\frac{A_f}{V_c} \left[\sum_m \left(-\omega^2 \bar{q}_m(\omega) L_{nm}^c \right) \right]}{\left(-\omega^2 + \omega_n^{c2} \right)} \quad (95)$$

$$\bar{P}_n^e(\omega) = \frac{\frac{A_f}{V_e} \sum_m \left(-\omega^2 \bar{q}_m(\omega) L_{nm}^e \right)}{\left(-\omega^2 + \omega_n^{e2} \right)} \quad (96)$$

$$0 = A_f \sum_n \frac{-A_f}{V_c} \sum_m \frac{\left(-\omega^2 \bar{q}_m L_{nm}^c \right)}{\left(\omega_n^{c2} - \omega^2 \right)} \frac{L_{nr}^c}{M_n^c}$$

$$- A_f \sum_n \frac{A_f}{V_e} \sum_m \frac{-\omega^2 \bar{q}_m L_{nm}^e}{\left(\omega_n^{e2} - \omega^2 \right)} \frac{L_{nr}^e}{M_n^e}$$

$$0 = \frac{-A_f^2}{V_c} \sum_n \frac{1}{M_n^c} \frac{\left(-\omega^2 \right)}{\left(\omega_n^{c2} - \omega^2 \right)} \sum_m L_{nm}^c L_{nr}^c \bar{q}_m$$

$$- \frac{A_f^2}{V_e} \sum_n \frac{1}{M_n^e} \frac{-\omega^2}{\left(\omega_n^{e2} - \omega^2 \right)} \sum_m L_{nm}^e L_{nr}^e \bar{q}_m$$

Divide out $(-\omega^2)$ and let

$$Q_{rm} = \left[\frac{A_f^2}{V^c} \sum_n \frac{L_{nm}^c L_{nr}^c}{(\omega_n^{c2} - \omega^2) M_n^c} + \frac{A_f^2}{V^e} \sum_n \frac{L_{nm}^e L_{nr}^e}{(\omega_n^{e2} - \omega^2) M_n^e} \right] \quad (-1)$$

Then

$$\sum_m Q_{rm} \bar{q}_m = 0 \quad r = 1, 2, 3, \dots$$

The natural frequencies are determined by the condition that the determinant of the coefficients must vanish.

$$|Q_{rm}| = 0$$

Equations 95 and 96 can be substituted into equation 94 to obtain a nonstandard eigenvalue problem. Once the eigenvalues and eigenvectors of the system of equations have been found, equations 95 and 96 can be used to obtain $\bar{P}_n^c(\omega)$ and $\bar{P}_n^e(\omega)$. With these values, the mode shape of the multiple cavity system can be calculated.

Within cavity c:

$$F_{n'}^c(x_o) = \sum_n \frac{\bar{P}_n^c(\omega) F_n^e(x_o)}{M_n^c} \quad (97)$$

And within cavity e:

$$F_{n'}^e(x_o) = \sum_n \frac{\bar{P}_n^e(\omega) F_n^c(x_o)}{M_n^e} \quad (98)$$

Again, the normal modes and mode shapes for a complex cavity can be obtained by the process of component mode synthesis. The required input to the process is the hard wall normal modes and mode shapes of the subcavities which approximate the complex shape.

2.2.2 Generalized Acoustic Mass of the Multiple Cavity System

The generalized mass of the multiple cavity system, needed for the calculation of the internal pressure, is defined as

$$M_{nn'}^A = 1/V \int_V F_n(x_o) F_{n'}(x_o) dV \quad (99)$$

where $F_n(x_o)$ and $F_{n'}(x_o)$ are mode shapes of the multiple cavity system. Recall from equation 98:

$$F_n(x_o) = \sum_m \frac{P_m^V(\omega_n) F_m^V(x_o)}{M_m^{sc}}$$

$$F_{n'}(x_o) = \sum_r \frac{P_r^V(\omega_{n'}) F_r^V(x_o)}{M_r^V}$$

where $P_m^V(\omega_n)$ and $P_r^V(\omega_{n'})$ are constraint constants from the acoustic component synthesis with v denoting the subvolume when used in conjunction with other variables and denoting the volume of the subvolume when used alone. Capital V denotes the volume of the multiple cavity system as a whole.

$$M_{nn'}^a = \frac{1}{V} \left(\int_V \sum_m \frac{P_m^V(\omega_n) F_m^V(x_o)}{M_r^V} \cdot \sum_r \frac{P_r^V(\omega_{n'}) F_r^V(x_o)}{M_r^V} \right) dV \quad (100)$$

Break this integral down into the sum of the integrals over the subvolumes of the cavity.

$$M_{nn'}^a = \sum_{v=1}^{nv} \frac{1}{V} \cdot \left[\int_V \sum_m \sum_r \frac{P_m^V(\omega_n) P_r^V(\omega_{n'})}{M_m^V M_r^V} F_m^V(x_o) F_r^V(x_o) dv \right]$$

nv = number of subvolumes in the multiple cavity system

v = subcavity.

$$M_{nn'}^a = \sum_{v=1}^{nv} \frac{1}{V} \cdot \left[\sum_m \sum_r \frac{P_m^v(\omega_n) P_r^v(\omega_{n'})}{M_m^v M_r^v} \int_v F_m^v(x_o) F_r^v(x_o) dv \right]$$

Since $F_m^v(x_o)$ and $F_r^v(x_o)$ are normal modes of the subcavity v , the integral is zero where $m \neq r$, and $v \cdot M_m^v$ where $m = r$. Hence,

$$M_{nn'}^a = \sum_{v=1}^{nv} \frac{1}{V} \left[v \cdot \sum_m \frac{P_m^v(\omega_n) P_m^v(\omega_{n'})}{M_m^v} \right] \quad (101)$$

$P_m^v(\omega_n)$ and $P_m^v(\omega_{n'})$ are known from multiple cavity component mode synthesis calculations. Since the modes of the multiple cavity system are also orthogonal, the generalized mass, $M_{nn'}^a = 0$ when $n \neq n'$.

2.2.3 Space-Averaged Pressure Over a Subvolume of a Multiple Cavity System

The space-averaged pressure squared over a subvolume of a multiple cavity system can be calculated. Recall equation 67:

$$p^2(x_o, \omega) = \frac{1}{2} \rho^2 c^4 \sum_n \sum_{n'} \frac{P_n(\omega) P_{n'}^*(\omega)}{M_n^a M_{n'}^a} F_n(x_o) F_{n'}(x_o)$$

Take the integral over the subvolume V_P ,

$$p^2(x_o, \omega) = \frac{1}{2} \rho^2 c^4 \sum_n \sum_{n'} \frac{P_n(\omega) P_{n'}^*(\omega)}{M_n^a M_{n'}^a} \frac{1}{V} \int_v F_n(x_o) F_{n'}(x_o) dv \quad (102)$$

Since $F_n(x_o)$ and $F_{n'}(x_o)$ are mode shapes of the multiple cavity system and not the subvolume, the volume integral is not necessarily zero when $n \neq n'$. To calculate the integral, recall that the multiple cavity mode shapes can be calculated from the constraint constants from the component mode synthesis.

$$F_n(x_o) = \sum_m \frac{P_m^v(\omega_n) F_m^v(x_o)}{M_m^v}$$

$$F_{n'}(x_o) = \sum_r \frac{P_r^v(\omega_{n'}) F_r^v(x_o)}{M_r^v}$$

Substitute into the integral

$$\begin{aligned} \frac{1}{v} \int_v F_n(x_o) F_{n'}(x_o) dv_{\text{sub}} &= \frac{1}{v} \int_v \sum_r \sum_m \frac{P_m^v(\omega_n) F_m^v(x_o)}{M_m^v} \\ &\quad \cdot \frac{P_r^v(\omega_{n'}) F_r^v(x_o)}{M_r^v} dv \\ &= \sum_r \sum_m \frac{P_m^v(\omega_{n'}) F_r^v(\omega_{n'})}{M_m^v M_r^v} \\ &\quad \cdot \frac{1}{v} \int_v F_m^v(x_o) F_r^v(x_o) dv \end{aligned}$$

Since $F_m^v(x_o)$ and $F_r^v(x_o)$ are mode shapes of the subvolume, v , the integral is zero when $m \neq r$ and M_m^v when $m = r$. Hence,

$$\frac{1}{v} \int_v F_n(x_o) F_{n'}(x_o) dv = \sum_m \frac{P_m^v(\omega_n) P_m^v(\omega_{n'})}{M_m^v} \quad (103)$$

Substitute equation 103 into 102 to obtain

$$\begin{aligned} \langle p^2(x_o, \omega) \rangle &= \frac{1}{2} \rho^2 c^4 \sum_n \sum_{n'} \frac{P_n(\omega) P_{n'}^*(\omega)}{M_n^a M_{n'}^a} \\ &\quad \cdot \sum_m \frac{P_m^v(\omega_n) P_m^v(\omega_{n'})}{M_m^v} \end{aligned} \quad (104)$$

For random excitation, take the expected value of equation 104:

$$\begin{aligned} \langle S_p(\omega) \rangle_v &= \sum_n \sum_{n'} \frac{1}{2} \rho^2 c^4 \frac{E [P_n(\omega) P_n^*(\omega)]}{M_n^a M_{n'}^a} \\ &\cdot \left[\sum_m \frac{P_m^v(\omega_n) P_m^v(\omega_{n'})}{M_m^v} \right] \end{aligned} \quad (105)$$

Recall the relationship expressed in equation 79.

$$\frac{1}{2} E [P_n(\omega) P_{n'}^*(\omega)] = A^2 S_{pbl}(\omega) \sum_s \sum_r I_{ns} I_{n'r}^* J_{sr}^2$$

and substitute into equation 105 to obtain

$$\begin{aligned} \langle S_p(\omega) \rangle_v &= \sum_n \sum_{n'} \rho^2 c^4 \frac{1}{M_n^a M_{n'}^a} \sum_m \left[\frac{P_m^v(\omega_n) P_m^v(\omega_{n'})}{M_m^v} \right] \\ &\cdot A^2 S_{pbl}(\omega) \sum_s \sum_r I_{ns} I_{n'r}^* J_{sr}^2 \end{aligned}$$

Again, neglecting the cross-coupling terms, J_{sr}^2 , as done in equation 81,

$$\begin{aligned} \langle S_p(\omega) \rangle_v &= \rho^2 c^4 \sum_n \sum_{n'} \frac{1}{M_n^a M_{n'}^a} \left[\sum_m \frac{P_m^v(\omega_n) P_m^v(\omega_{n'})}{M_m^v} \right] \\ &\cdot A^2 S_{pbl}(\omega) \sum_r I_{nr} I_{n'r}^* J_{rr}^2 \end{aligned} \quad (106)$$

The double summation of n and n' in equation 106 can be a very lengthy process. An approximation for the subcavity average internal pressure can be obtained by neglecting the cross terms nn' . This assumes

$$\sum_m P_m^v(\omega_n) P_m^v(\omega_{n'}) \ll \sum_m \left(P_m^v(\omega_n) \right)^2$$

which is the same as asserting

$$\int_v F_n(x_o) F_{n'}(x_o) dv \ll \int_v F_n^2(x_o) dv$$

Applying this assumption to equation 106,

$$\begin{aligned} \langle S_p(\omega) \rangle_v &= \rho^2 c^4 \sum_n \frac{1}{M_n^a} \cdot C_{nn}^v \\ &\quad \cdot A^2 S_{pbl}(\omega) \sum_r |I_{nr}|^2 J_{rr}^2 \end{aligned} \quad (107)$$

where

$$C_{nn}^v = \sum_m \frac{\left(P_m^v(\omega_n) \right)^2}{M_m^v M_n^a}$$

2.2.4 Multiple Panels

When an enclosure is constructed of several walls, each having separate response characteristics, the internal pressure can be calculated by the linear superposition of the contributions from each panel. For example, the pressure at a point and frequency can be calculated by

$$\langle p(x_o, \omega) \rangle = \sum_{\text{panels}} \left(\frac{1}{2} \rho^2 c^4 \sum_n \frac{P_n^*(\omega) P_n(\omega)}{M_n^a} \right) \quad (108)$$

Since the acoustic constants in equation 108 are independent of the panel structural response, the equation can be written

$$\langle p^2(x_o, \omega) \rangle = \frac{\rho^2 c^4}{2} \sum_n \frac{1}{M_n^a} \sum_{\text{panels}} (P_n^*(\omega) P_n(\omega)) \quad (109)$$

2.2.5 Modal Summations

The multiple summations required by the modal analysis method can become excessively time consuming if one sums over all the structural and acoustic modes at each band. Recall equation 82, which gives the space-averaged, band-averaged pressure squared in the volume

$$\int_{\omega_1}^{\omega_2} S_p(\omega) d\omega = A^2 \rho^2 c^4 \sum_n \frac{1}{M_n^a} \cdot S_{pbl}(\omega_c) \sum_m J_{mm}^2(\omega_c) \int_{\omega_1}^{\omega_2} |I_{nm}|^2 d\omega$$

where

$$|I_{nm}|^2 = \frac{A_f^2 L_{nm}^2}{V^2 M_m^2} \cdot \frac{\omega^4}{\left((\omega_n^a)^2 - \omega^2 \right)^2 + 4\zeta_n^2 \omega_n^a \omega^2} \left((\omega_m^2 - \omega^2)^2 + 4\zeta_m^2 \omega_m^2 \omega^2 \right)$$

The further ω_n and ω_m are from the band of interest, the smaller value of the integral. This fact forces the series to converge to a solution. Criteria which limit the computations to only those modes that significantly contribute to the solution are developed in this section.

The outermost summation is over the acoustic modes of the cavity. Consider a frequency band centered at ω_c with ω_1 and ω_2 as the lower and upper frequency limits. The acoustic natural frequencies closest to the center frequency, ω_c , will contribute the most to the solution. The magnitude of the frequency separation between ω_c and ω_n after which one can consider the acoustic modal contribution

negligible is a function of the accuracy desired, the number of acoustic modes close to ω_c , and the acoustic damping. When examining the acoustic modal summation, one must compare the acoustic modal contributions using an arbitrary structural mode as a constant. For simplicity, assume $\omega_m = \omega_c$, hence

$$|I_{nm}|^2 = \frac{A_f^2 L_{nm}^2}{V^2} \cdot \frac{\omega^2}{\left[(\omega_c^2 - \omega^2)^2 + 4\zeta_m^2 \omega_c^2 \omega^2 \right]} \cdot \frac{\omega^2}{\left[(\omega_n^2 - \omega^2)^2 + 4\zeta_n^2 \omega_n^2 \omega^2 \right]} \quad (110)$$

Since $\omega_c \sim \omega$ over the one-third-octave band, ω_1 to ω_2 ,

$$|I_{nm}|^2 = \frac{A_f^2 L_{nm}^2}{V^2} \cdot \frac{\omega_c^2}{4\zeta_m^2 \omega_c^4} \cdot \frac{\omega^2}{\left[(\omega_n^2 - \omega^2)^2 + 4\zeta_n^2 \omega_n^2 \omega^2 \right]} \quad (111)$$

Normalize $|I_{nm}|^2$ by $\frac{V^2 4\zeta_m^2 \omega_c^2}{A_f^2 L_{nm}^2}$ and integrate over the one-third octave band around ω_c to obtain an acoustic modal proximity weighting factor, W^a ,

$$W^a = \int_{\omega_1}^{\omega_2} \left(\frac{\omega^2}{(\omega_n^2 - \omega^2)^2 + 4\zeta_n^2 \omega_n^2 \omega^2} \right) d\omega \quad (112)$$

By establishing a base weight, W_b^a , equal to the value of W^a at the ω_n closest to ω_c , a criterion for modal importance can be defined:

If $\frac{W^a}{W_b^a} < \epsilon$ then the ω_n is not important to the solution in that band,

where ϵ is some fraction of the contribution of the nearest acoustic natural frequency, ω_b^a .

The structural criteria follow the same development to yield

$$W^S = \int_{\omega_1}^{\omega_2} \left(\frac{\omega^2}{(\omega_m^2 - \omega^2)^2 + 4\zeta_m^2 \omega_m^2 \omega^2} \right) d\omega \quad (113)$$

The weighting factor integral, W , can be analytically evaluated over any band of interest to obtain the bandwidth of importance:

$$\text{Band} = |\omega_c - \omega_n(\epsilon)| \quad (114)$$

$\omega_n(\epsilon)$ is the frequency above which the equation

$$W - W_b \leq \epsilon W_b \quad (115)$$

holds. W_b in equation 115 is the weighting factor integral for the closest mode to the band. W is the weighting factor integral at the frequency $\omega_n(\epsilon)$.

To limit the extent of this task, the program implements this analysis technique with a few simplifying assumptions. In calculating the acoustic bandwidth of importance around each band of interest, the highest damping for any cavity mode is assumed for all the cavity modes. In calculating the structural bandwidth of importance around each band of interest, the highest damping for any mode of the structural wall of the cavity is also assumed for all the structural modes. The modal summations of each structure is considered separately.

2.2.6 Point Excitation

With use of the delta function, point excitation of the structural wall can be considered. In this section, the generalized driving force for both the deterministic and random cases will be defined for a point force. Let

$x = x_f$ be the location of the point excitation
and $F(x_f, t)$ be the time history of the force at that point.

$$p^e(x_o, t) = \delta(x_o - x_f) F(x_f, t) \quad (116)$$

$\delta(x - x_f)$ is the delta function

$$Q_m^{bl}(t) = \iint_S p^e(x_o, t) \psi_m(x_o) ds \quad (\text{eq. 37})$$

$$Q_m^{bl}(t) = \iint_S \delta(x_o - x_f) F(x_f, t) \psi_m(x_o) ds \quad (117)$$

Hence,

$$Q_m^{bl}(t) = F(x_f, t) \psi_m(x_f) \quad (118)$$

This, of course, also translates to the frequency domain,

$$Q_m^{bl}(\omega) = F(x_f, \omega) \psi_m(x_f) \quad (119)$$

For random vibration,

$$P_n(\omega) = \sum_m I_{nm}(\omega) \iint_S \delta(x_o - x_f) F(x_f, \omega) \psi_m(x_o) ds \quad (120)$$

$$P_n^*(\omega) = \sum_s I_{ns}(\omega) \iint_S \delta(x_o - x'_f) F^*(x'_f, \omega) \psi_s(x'_o) ds \quad (121)$$

Since $x'_f = x_f$ for point force excitation,

$$\begin{aligned} 1/2 E [P_n^*(\omega) P_n(\omega)] &= \sum_s \sum_m I_{ns}^*(\omega) I_{nm}(\omega) E [|F(x_f, \omega)|^2] \\ &\quad \cdot \psi_s(x_f) \psi_m(x_f) \end{aligned} \quad (122)$$

where $E [|F(x_f, \omega)|^2]$ is the expected value of the mean squared force at point x_f .

2.2.7 Reverberation Time

The low frequency formulation lends itself to the calculation of the reverberation time of an arbitrarily shaped cavity with walls of unequal absorption characteristics. The equations needed for the calculation of the reverberation time are presented below. This particular application was first presented by Dowell and is fully developed in reference 3. Several important points about reverberation time, absorption, and impedance are made in his paper based on equations also used in VIN's modal analytical

model. However, only reverberation time will be discussed here. Recall equations 21 and 28:

$$p(x_o, t) = \rho c^2 \sum_n \frac{F_n(x_o)}{M_n^a} \cdot P_n(t) \quad (123)$$

and

$$\frac{\partial^2 P_n(t)}{\partial t^2} + \frac{A_c}{V} \rho c^2 \sum_r \frac{C_{nr}}{M_r^a} \frac{\partial P_r(t)}{\partial t} + \omega_n^2 P_n(t) = 0 \quad (124)$$

where the RHS of equation 124 was set to zero to represent the unforced condition considered in reverberation time. All symbols are as previously defined.

Reverberation time is defined as the time required for the diffuse pressure in a room to decay 60 dB after the pressure generating source is turned off. Given initial conditions at $p(x_o, 0)$, $\partial p / \partial t(x_o, 0)$, the pressure in the room can be calculated with the above equations. One has several choices for these initial conditions because of the imprecise definition of "diffuse" pressure field. One could simply require the pressure to be initially uniform ($p(x_o, t) = \dot{p}(x_o, 0) = \text{constant}$), or the potential energy in each mode to be equal ($P_n^2(t=0)/M_n = \text{const}$ for all n), or the kinetic energy in each mode to be constant. In addition, one must specify where the pressure decay is to be measured or define an overall measure of room pressure, such as a volume averaged rms level.

$$p_{av} \equiv \left(\frac{1}{V} \int_V p^2(x_o, t) dV \right)^{1/2}$$

as developed in section 2.2.3, this results in

$$p_{av}(t) = \rho_o c_o^2 \left(\sum_n P_n^2(t) / M_n \right)^{1/2} \quad (125)$$

Dowell shows that the damping coupling between the modes is usually small, hence $C_{nr} \rightarrow 0$ and can be neglected. The controlling equation becomes

$$\frac{\partial^2 (P_n(t))}{\partial t^2} + \frac{A_a}{V} \rho c^2 \frac{C_{nn}}{M_n^a} \frac{\partial P_n(t)}{\partial t} + \omega_n^2 P_n(t) = 0 \quad (126)$$

The solution to this equation for $n > 0$ is

$$\begin{aligned}
 P_n(t) = & \exp(-\delta_{nn} \omega_n^a t) \left(P_n(0) \cos \left(\omega_n^a (1 - \delta_{nn}^2)^{1/2} t \right) \right. \\
 & + \left(\left(\frac{\partial P_n(0)}{\partial t} + \delta_{nn} \omega_n^a P_n(0) \right) / \left(\omega_n^a (1 - \delta_{nn}^2)^{1/2} \right) \right) \\
 & \cdot \sin \left(\omega_n^a (1 - \delta_{nn}^2)^{1/2} t \right)
 \end{aligned} \tag{127}$$

where $2\delta_{nn} \omega_n^a \equiv A_a \rho_o c_o^2 C_{nn} / (V M_n)$, as before, if $\delta_{nn} \ll 1$, as is usually the case,

$$\begin{aligned}
 P_n(t) \approx & \exp(-\delta_{nn} \omega_n^a t) \left(P_n(0) \cos \omega_n^a t \right) \\
 & + \left(\frac{\partial P_n(0)}{\partial t} + \delta_{nn} \omega_n^a P_n(0) \right) / \omega_n^a \sin \omega_n^a t \quad (n > 0)
 \end{aligned} \tag{128}$$

For $n = 0$, the Helmholtz mode, the solution to the governing equation is

$$P_0(t) = \frac{\partial P_0(0)}{\partial t} \left(1 - \exp(-2\delta_0 \omega_0^a t) \right) / (2\delta_0 \omega_0^a) + P_0(0) \tag{129}$$

where $2\delta_0 \omega_0^a = A_n \rho_o c_o^2 C_{nn} / (V M_n) / 2A_a \neq 0$

With appropriate selection of initial conditions, the space averaged reverberation time can be calculated. The terms required for the calculations are all also required for the modal method of noise transmission analysis. Hence, the reverberation time calculations can easily be added to the computer program VIN using equations 127, 128 and 129. Of course, the band filtered reverberation time can also be calculated.

2.2.7 Retransmission of Sound

The fundamental equations implicitly include the effect of the internal pressure on the net generalized force on the structural wall. Direct inclusion of this effect, however, couples the structural and acoustic equations (see equations 48 and 49). The effect of the internal pressure on the motion of the structural wall is often neglected to uncouple the equations (as in equation 62) and significantly simplify the calculations. An approximate allowance can be made for the retransmission of sound by noting that the process is essentially linear. The interior and exterior pressures, p_i and p_o respectively, are related by

$$\left(p_i^2\right)_v = A p_o^2,$$

where $()_v$ denotes in vacuo shell response (that is, the effect of interior pressure), is not considered. Counting interior pressure,

$$p_i^2 = A \left[p_o^2 - \left(p_i^2\right)_v \right].$$

The equation assumes the process is reversible. If only a single mode is considered, this is true. Since the present approximation has structural modes uncorrelated with each other, and acoustic modes are uncorrelated in the spatial average, this is a reasonable assumption. At low frequencies, there are few modes present, so the approximation is reasonable from this viewpoint as well. At high frequencies, where there are many overlapping modes, the SEA portion of the program is a more appropriate model for vehicle interior noise prediction.

Section 3

STATISTICAL ENERGY ANALYSIS

Theoretically, the model presented in section 2 is good for the entire frequency range. As a practical matter, the computation time required by the method will become prohibitively expensive as the number of structural and acoustical modes in each frequency band becomes large. The statistical energy analysis (SEA) method presented in this section is used in VIN when the acoustic modal density becomes sufficient to justify the required SEA assumptions. This particular SEA formulation is a modification of the high-frequency model used in PACES⁽⁴⁾. It allows the calculation of the average noise level within predefined subvolumes of a vehicle given a random external pressure field on the vehicle structure. In VIN, the SEA subvolumes are defined to match those used in the low-frequency analysis portion of the program to facilitate the transition between the low- and high-frequency models. A very good summary of the general idea of SEA was given by Trudell and Yano⁽⁵⁾ in the preface to a structurally oriented SEA computer program:

Statistical Energy Analysis (SEA) is a powerful tool for estimating the high frequency vibration spectra of complex systems. The analysis method is based on the estimation of the power flow between idealized gross elements of a vibrating system. The method is statistical in that averaging assumptions are made with regard to distribution of energy within an element, distribution of resonant modes, and the coupling between elements. These assumptions greatly simplify the computational complexity associated with normal mode methods. These same assumptions impose the limitation and point response predictions cannot be made.

The assumptions on which the method rests and their implications can be quite rigorously stated as follows:

1. The total vibrating system can be partitioned into SEA elements (with suitable boundary conditions) whose modes approximate the modes of the original vibrating system.
2. The modes of the elements of a system contain all of the vibratory energy of the system.
3. The energy in one frequency band of a system element is equally distributed among the modes of that element occurring in the frequency band.

4. Only modes occurring within the same frequency band are coupled.
5. For two coupled elements, all of the modes occurring in one of the elements in one frequency band are equally coupled to each mode occurring in the same frequency band in the other element.

Assumption 1 contains the fundamental existence basis for SEA: the concept of partitionability. This concept implies that a coupled vibrating system with system modes can be approximated by two or more separately idealized vibrating elements, each with its own independent mode set. These sets are coupled only in the sense of having power flow to and from each set across the partition boundary (later referred to as the "joint"). The approximation to this model exists in most structures having reflective boundaries in the higher frequencies. For example, a skin/stringer structure has higher order skin panel modes that are nearly the same frequency and shape as an ideally supported panel because the stringer is a comparatively massive boundary causing reflection of flexural waves from the skin panel. An SEA plate element could logically be equal to the panel area bounded by stringers or frames. Such elements will then have to be coupled with joint elements in order to develop an SEA model which emulates the vibratory power flow of the real structure.

(Another example is a structural/acoustical problem where the modes of the cavity and the modes of the structure can be considered separately.)

Assumption 3 is the most important simplifying assumption of SEA because it eliminates the necessity to calculate generalized modal forces and responses. The conditions implicit in this assumption are usually approximated by the higher order modes of a structure in a reasonable bandwidth, say 1/3 octave. One-third octave bands represent a reasonable compromise between the necessity to get a fairly large number of modes (>10) in the band for good statistics and the necessity to have some frequency response resolution in the vibration prediction. The number of modes in a unit bandwidth can be estimated for simple structural forms (such as beams, plates, etc.) using algebraic expressions for modal density such as those given in Section 4 of this report. Estimation of modal density in this way is a considerable simplification over normal mode methods.

Given SEA elements with the properties described above it is now necessary to join them to permit power flow between the modes of one element and the modes of another. This is done with a parameter called the coupling loss factor η and leads to assumptions 4 and 5. Assumption 4 is directly linked to assumption 2 and the further assumption of a linear process. Assumption 5 follows directly from assumption 3 as part of the simplification associated with a statistical rather than explicit description of modes.

In this particular application (vehicle acoustics), an energy balance equation is written for each cavity of a multiple cavity system and a matrix equation is prepared.

$$\{W\} = [C] \{p^2\}, \quad (130)$$

where

$\{W\}$ is a column vector containing the system external input power to each cavity of the system

$\{p^2\}$ is a column vector of the internal space-averaged, band-averaged pressure squared for each cavity of the system

$[C]$ is a square matrix holding factors that account for the energy stored and dissipated within each subvolume of the multiple cavity system.

The band-average internal pressure squared is then found with

$$\{p^2\} = [C]^{-1} \{W\}$$

The derivation of each matrix will be fully described in this section.

3.1 Fundamental Model for Power Input Into Cavity from Structural Wall

A vehicle structure will respond to excitation by a random pressure field according to the frequency domain relation

$$W(x_o, \omega) = \int G(x_o | x'_o; \omega) [p^e(x'_o, \omega) - p^i(x'_o, \omega)] dx'_o \quad (131)$$

where

$G(x_o | x'_o, \omega)$ is the structure's Green's function

$p^2(x'_o, \omega)$ is the external exciting pressure

$p^i(x'_o, \omega)$ is the induced interior pressure on the structure

$W(x_o, \omega)$ is the displacement of the structure

The internal pressure field is related to the vehicle wall motion by⁽⁴⁾

$$p^i(x'_o, \omega) = -\rho\omega^2 \int G_p(x_o | x'_o; \omega) W(x_o, \omega) dx_o \quad (132)$$

where $G_p(x_o|x'_o; \omega)$ is the Green's function for the vehicle's interior.

The external pressure field is the sum of the pressure imposed on the surface by external sources and the pressure resulting from the motion of the structure.⁽⁶⁾

$$p^e(x'_o, \omega) = P_{bl}(x'_o, \omega) + \rho \omega^2 \int G_p^e(x_o|x'_o; \omega) W(x_o, \omega) dx_o \quad (133)$$

where

$G_p^e(x_o|x'_o; \omega)$ is the exterior field Green's function with the source point on the structure

$P_{bl}(x'_o, \omega)$ is the transformed pressure

Define

$$W(x_o, \omega) = \sum_r q_r(\omega) \psi_r(x_o) \quad (134)$$

$$p^i(x_o, \omega) = \sum_r m D_r(\omega) \psi_r(x_o) \quad (135)$$

where

$\psi_r(x_o)$ is the in vacuum normal shell modes of the structure

m is the areal mass

$D_r(\omega)$ is the shell dynamics or modal acceleration term

substituting equations 134 and 135 into equation 133, transferring all terms to the left-hand side, and changing one of the summation indices for clarity,

$$\left[\sum_r m D_r(\omega) \psi_r(x_o) \right] + \rho \omega^2 \int_{x_o} G_p^e(x_o|x'_o; \omega) \left[\sum_n q_n(\omega) \psi_n(\omega) \right] dx_o = 0 \quad (136)$$

which can also be written as

$$\left[\sum_{\mathbf{r}} m D_{\mathbf{r}}(\omega) \psi_{\mathbf{r}}(x_0) \right] + \rho \omega^2 \left[\sum_{\mathbf{n}} \int_{x_0} G_p^e(x_0 | x'_0; \omega) \psi_{\mathbf{n}}(x'_0) dx'_0 q_{\mathbf{n}}(\omega) \right] = 0 \quad (137)$$

To determine the $q_{\mathbf{n}}(\omega)$ for each frequency orthogonality may be used by multiplying through by $\psi_{\mathbf{r}'}(x_0)$ and integrating over the surface of the shell

$$\int_{x_0} \left[\sum_{\mathbf{r}} m D_{\mathbf{r}}(\omega) \psi_{\mathbf{r}}(x_0) \psi_{\mathbf{r}'}(x_0) \right] dx_0 + \rho \omega^2 \sum_{\mathbf{n}} \left[\int_{x_0} \psi_{\mathbf{r}'}(x_0) \int_{x'_0} G_p^e(x_0 | x'_0; \omega) \psi_{\mathbf{n}}(x'_0) dx'_0 dx_0 \right] q_{\mathbf{n}}(\omega) = 0 \quad (138)$$

Because of the orthogonality, where

$$\int_{x_0} \psi_{\mathbf{r}}(x_0) \psi_{\mathbf{r}'}(x_0) dx_0 = 0 \quad \text{if } \mathbf{r} \neq \mathbf{r}'$$

equation 138 becomes the fundamental acoustic equation

$$\int_{x_0} m D_{\mathbf{r}}(\omega) \psi_{\mathbf{r}}^2(x_0) dx_0 + \rho \omega^2 \sum_{\mathbf{n}} \left[\int_{x_0} \psi_{\mathbf{r}}(x_0) \int_{x'_0} G_p^e(x_0 | x'_0; \omega) \psi_{\mathbf{n}}(x'_0) dx'_0 dx_0 \right] q_{\mathbf{n}}(\omega) = 0 \quad (139)$$

Recall equation 131 and substitute equations 134 and 135 into it.

$$\sum_{\mathbf{r}} \psi_{\mathbf{r}}(x_0) q_{\mathbf{r}}(\omega) = \int_{x_0} G(x_0 | x'_0; \omega) p^e(x_0, \omega) dx_0 - \int_{x_0} G(x_0 | x'_0; \omega) \left[\sum_{\mathbf{r}} m D_{\mathbf{r}} \psi_{\mathbf{r}}(x_0) \right] dx_0 \quad (140)$$

This is the fundamental structural equation in terms of normal mode expressions. Proceeding, the definition of the Green's function of the structure as developed from LaGrangian equations is

$$G(x_o | x'_o; \omega) = \sum_r \frac{\psi_r(x_o) \psi_r(x'_o)}{M_r Y_r(\omega)} \quad (141)$$

where

M_r is the modal mass defined as $\int_{x_o} m \psi_r^2(x) dx_o$

$Y_r(\omega) \equiv (\omega_r^2 - \omega^2) - i \eta \omega_r^2$

ω_r is the natural frequency of mode r

η is the structural loss factor (energy dissipation term)

ω is the exciting frequency

Substitute equation 141 into 140.

$$\begin{aligned} \sum_r \psi_r(x_o) q_r(\omega) &= \int_{x_o} G(x_o | x'_o; \omega) p^e(x_o, \omega) dx_o \\ &= \int_{x_o} \left[\sum_t \frac{\psi_t(x_o) \psi_t(x'_o)}{M_t Y_t(\omega)} \right] \left[\sum_r m D_r \psi_r(x_o) dx_o \right] \end{aligned} \quad (142)$$

Working with the underlined term of equation 142, combine the summations.

$$\sum_t \sum_r \frac{\psi_t(x) D_r(\omega)}{M_t Y_t(\omega)} \int_{x_o} m \psi_t(x_o) \psi_r(x_o) dx_o$$

Again, orthogonality simplifies things, and the term becomes

$$\sum_t \frac{\psi_t(x_o) D_t(\omega)}{M_t Y_t(\omega)} \int_{x_o} m \psi_t^2(x_o) dx_o$$

Since $\int_{x_o} m \psi_t^2(x_o) dx_o = M_t$, it further reduces to

$$\sum_t \frac{\psi_t(x_o) D_t(\omega)}{Y_t(\omega)}$$

Substitute this term back into equation 142 from whence it came.

$$\begin{aligned} \sum_r \psi_r(x_o) q_r(\omega) &= \int_{x_o} G(x_o | x'_o; \omega) p^e(x_o) dx_o \\ &- \sum_t \frac{\psi_t(x_o) D_t(\omega)}{Y_t(\omega)} \end{aligned} \quad (143)$$

To further simplify equation 143, multiply through by $m \psi_s(x_o)$ and integrate over the surface to obtain

$$\begin{aligned} M_r q_r(\omega) + \frac{D_r(\omega) M_r}{Y_r(\omega)} \\ = \int_{x_o} m \psi_r(x_o) \int_{x'_o} G(x_o | x'_o; \omega) P^e(x_o, \omega) dx'_o dx_o \end{aligned} \quad (144)$$

Substitute the equation for the Green's function of equation 141 into 144.

$$\begin{aligned} M_r q_r(\omega) + \frac{D_r(\omega) M_r}{Y_r(\omega)} \\ = \int_{x_o} m \psi_r(x_o) \int_{x'_o} \sum_t \frac{\psi_t(x_o) \psi_t(x'_o)}{M_t Y_t} p^e(x_o, \omega) dx'_o dx_o \end{aligned}$$

Rearrange

$$M_r q_r(\omega) + \frac{D_r(\omega) M_r}{Y_r(\omega)} = \sum_t \left[\int_{x_o} \psi_t(x_o) p^e(x_o, \omega) dx_o \right] \cdot \frac{1}{M_t Y_t} \int_{x'_o} m \psi_r(x'_o) \psi_t(x'_o) dx'_o \quad (145)$$

Orthogonality makes the right-hand side of equation 145 equal to zero for all $t \neq r$, hence

$$M_r q_r(\omega) + \frac{D_r(\omega) M_r}{Y_r(\omega)} = \frac{1}{Y_r} \int_{x_o} p^o(x_o) \psi_r(x_o, \omega) dx_o \quad (146)$$

This equation expresses the shell dynamics of the vehicle structure.

Define the generalized force on the structure.

$$Q_r(\omega) = \int_{x_o} p^e(x_o, \omega) \psi_r(x_o) dx_o \quad (147)$$

Substitute 147 into 146 and solve for the unknown $D_r(\omega)$.

$$D_r(\omega) = \frac{Q_r(\omega)}{M_r} - Y_r(\omega) q_r(\omega) \quad (148)$$

Equation 148 is simply a form of equation 131 obtained through several pages of contortions. This equation is used with a form of equation 132 by substituting equation 148 into equation 139. The result is an equation relating the modal response of a vehicle's shell to the internal acoustics of the vehicle (or cavity).

$$\begin{aligned} -Q_r(\omega) = & \left(\rho \omega^2 \int_{x_o} \psi_r(x_o) \int_{x'_o} G_p(x_o | x'_o; \omega) \psi_r(x'_o) dx'_o dx_o - M_r Y_r(\omega) \right) q_r(\omega) \\ & + \sum_{n \neq r} \left(\rho \omega^2 \int_{x_o} \psi_r(x_o) \int_{x'_o} G_p(x_o | x'_o; \omega) \psi_n(x'_o) dx'_o dx_o \right) q_n(\omega) \end{aligned} \quad (149)$$

Then,

$$-Q_r(\omega) = \left(\rho \omega^2 I_{rr} - M_r Y_r(\omega) \right) q_r(\omega) + \sum_{n \neq r} \rho \omega^2 I_{rn} q_n(\omega) \quad (150)$$

where

$$I_{rn} = \int_{x_0} \psi_r(x_0) \int_{x'_0} G_p(x_0 | x'_0; \omega) \psi_n(x'_0) dx'_0 dx_0$$

Equation 150 assumes the external pressure distribution is explicitly defined over the surface. Since the reradiated pressure term of equation 133 is sometimes significant, the equations can be developed to include those effects for theoretical completeness. It should be recognized, however, that the reradiated pressure effect can be neglected in most cases of interest.

Substitute equation 133--the definition of the external pressure field in terms of blocked pressure and reradiated pressure--into equation 147.

$$Q_r(\omega) = - \int_{x_0} \left[P_{bl}(x_0, \omega) + \rho \omega^2 \int_{x'_0} G_p^e(x_0 | x'_0, \omega) W(x'_0, \omega) dx'_0 \right] \psi_r(x_0) dx_0 \quad (151)$$

Then

$$\begin{aligned} Q_r(\omega) &= \int_{x_0} P_{bl}(x_0, \omega) \psi_r(x_0) dx_0 \\ &+ \rho \omega^2 \int_{x_0} \psi_r(x_0) \int_{x'_0} G_p^e(x_0 | x'_0, \omega) W(x'_0, \omega) dx'_0 \end{aligned} \quad (152)$$

Define

$$Q_r^{bl}(\omega) = \int_{x_0} P_{bl}(x_0, \omega) \psi_r(x_0) dx_0 \quad (153)$$

Recall equation 134 and substitute both into equation 152.

$$\begin{aligned}
 Q_r(\omega) &= Q_r^{bl}(\omega) + \rho\omega^2 \int_{x_0} \psi_r(x_0) \int_{x'_0} G_p^e(x_0 | x'_0; \omega) \sum_t q_t(\omega) \psi_t(x'_0) dx'_0 \\
 &= Q_r^{bl}(\omega) + \rho\omega^2 \left[\sum_t \int_{x_0} \psi_r(x_0) \int_{x'_0} G_p^e(x_0 | x'_0; \omega) \psi_t(x'_0) dx'_0 \right. \\
 &\quad \left. \cdot q_t(\omega) \right]
 \end{aligned} \tag{154}$$

Define

$$J_{rt} = \int_{x_0} \psi_r(x_0) \int_{x'_0} G_p^e(x_0 | x'_0; \omega) \psi_t(x'_0) dx'_0 \tag{155}$$

Substitute equations 155 into equation 154

$$Q_r(\omega) = Q_r^{bl}(\omega) + \rho\omega^2 \sum_t J_{rt} \cdot q_t(\omega) \tag{156}$$

Substitute 156 into equation 150.

$$\begin{aligned}
 \left(\rho\omega^2 I_{rr} - M_r Y_r(\omega) q_r(\omega) \right) + \sum_{n \neq r} \rho\omega^2 I_{rn} q_n(\omega) \\
 + \rho\omega^2 \sum_t J_{rt} \cdot q_t(\omega) = -Q_r^{bl}(\omega)
 \end{aligned} \tag{157}$$

Combine the t summation with the r and n.

$$\begin{aligned}
 \left(\rho\omega^2 (I_{rr} + J_{rr}) - M_r Y_r(\omega) q_r(\omega) \right) + \sum_{n \neq r} \rho\omega^2 (I_{nr} + J_{nr}) q_n(\omega) \\
 = -Q_r^{bl}(\omega)
 \end{aligned} \tag{158}$$

Equation 158 defines the shell dynamics given an external blocked pressure field. It is essentially the same equation that was used in the low frequency model (equation 41). The matrix form of equation 158 is

$$\begin{bmatrix} a_{rn} \end{bmatrix} \{ q_r(\omega) \} = \{ -Q_r^{bl}(\omega) \}$$

and has the solution

$$\{ q_r(\omega) \} = \begin{bmatrix} a_{rn} \end{bmatrix} \{ -Q_r^{bl}(\omega) \} \quad (159)$$

where $a_{rn} = \begin{bmatrix} a_{rn} \end{bmatrix}^{-1}$

Substitute for $q_r(\omega)$ in equation 134 from equation 159.

$$W(x_o, \omega) = - \sum_r \sum_n a_{rn} Q_r^{bl}(\omega) \psi_r(x_o) \quad (160)$$

The one-sided cross-power spectral density of displacement is defined:

$$S_w(x_o | x'_o; \omega) = \lim_{T \rightarrow \infty} \frac{2}{T} \frac{1}{2\pi} W(x_o, \omega) W^*(x'_o, \omega) \quad (161)$$

The Fourier transform is obtained over a sample length, T . All terms shown to be an explicit function of ω are implicitly a function of the sample length. Random processes are fully described in the frequency regime as the sample length is allowed to go to infinity and the random variable approaches a limiting value.

Substituting for $W(x_o, \omega)$ from equation 160,

$$\begin{aligned} S_w(x_o | x'_o; \omega) = & \lim_{T \rightarrow \infty} \frac{2}{T} \frac{1}{2\pi} \sum_r \sum_n \sum_s \sum_m a_{rn} a_{sm}^* \psi_r(x_o) \psi_s(x'_o) \\ & \cdot Q_r^{bl}(\omega) \cdot Q_s^{bl}(\omega) \end{aligned} \quad (162)$$

Recall that

$$Q_r^{bl(\omega)} \cdot Q_s^{bl(\omega)} = \int_{x_0} \int_{x'_0} P_{bl}(x_0, \omega) P_{bl}^*(x'_0, \omega) \psi_r(x_0) \psi_s(x'_0) dx'_0 dx_0$$

Let

$$S_{pbl}(x_0 | x'_0; \omega) = \lim_{T \rightarrow \infty} \frac{2}{T} \frac{1}{2\pi} P_{bl}(x_0, \omega) P_{bl}^*(x'_0, \omega) \quad (163)$$

Then

$$\begin{aligned} S_w(x_0 | x'_0; \omega) &= \sum_r \sum_n \sum_s \sum_m a_{rn} a_{sm}^* \psi_r(x_0) \psi_s(x'_0) \\ &\cdot \int_{x_0} \int_{x'_0} S_{pbl}(x_0 | x'_0; \omega) \psi_r(x_0) \psi_s(x'_0) dx'_0 dx_0 \end{aligned} \quad (164)$$

which is the one-sided cross-power spectral density of displacement.

The net power radiated into the cavity can now be calculated. The internal cross-power spectral density is

$$S_p(x_0 | x'_0; \omega) = \lim_{T \rightarrow \infty} \frac{2}{T} \left(\frac{i\omega}{2\pi} \right) p^i(x_0, \omega) W^*(x'_0, \omega) \quad (165)$$

Substitute for $p^i(x_0, \omega)$ from equation 132.

$$\begin{aligned} S_p(x_0 | x'_0; \omega) &= \lim_{T \rightarrow \infty} \frac{2}{T} \left(\frac{i\omega}{2\pi} \right) \\ &- \rho \omega^2 \int_{x''_0} G_p(x_0 | x''_0; \omega) W(x_0, \omega) W^*(x''_0, \omega) dx''_0 \end{aligned} \quad (166)$$

Using equation 161, equation 166 becomes

$$S_p(x_o | x'_o; \omega) = i \rho \omega^3 \int_{x''_o} G_p(x_o | x''_o; \omega) S_w(x''_o | x'_o; \omega) dx''_o \quad (167)$$

Let $x''_o \rightarrow x_o$ and integrate $S_p(x_o | x'_o; \omega)$ over the transmitting area of the structure to obtain the radiated power spectral density.

$$W_{rad}(\omega) = -i \rho \omega^3 \int_{x_o} \int_{x'_o} G_p(x_o | x'_o; \omega) S_w(x'_o | x_o; \omega) dx'_o dx_o \quad (168)$$

Using equation 164,

$$W_{rad}(\omega) = -i \rho \omega^3 \sum_r \sum_n \sum_s \sum_m a_{rn} a_{sm}^* \int_{x_o} \int_{x'_o} G_p(x_o | x'_o; \omega) \psi_r(x_o) \psi_s(x'_o) dx'_o dx_o \\ \cdot \int_{x''_o} \int_{x'''_o} S_{pbl}(x''_o | x'''_o; \omega) \psi_n(x''_o) \psi_m(x'''_o) dx''_o dx'''_o \quad (169)$$

which becomes

$$W_{rad}(\omega) = -i \rho \omega^3 A^2 S_{pbl}(\omega) \sum_{r,n,s,m} a_{rn} a_{sm}^* I_{rs}(\omega) J_{nm}^2(\omega) \quad (170)$$

where

$$I_{rs}(\omega) = \int_{x_o} \int_{x'_o} G_p(x_o | x'_o; \omega) \psi_r(x_o) \psi_s(x'_o) dx'_o dx_o$$

$$J_{nm}^2 = \frac{1}{A^2 S_{pbl}(\omega)} \int_{x_o} \int_{x'_o} S_{pbl}(x_o | x'_o; \omega) \psi_n(x_o) \psi_m(x'_o) dx'_o dx_o$$

$S_{pbl}(\omega)$ is the external blocked pressure spectrum and A is the surface area.

J_{nm}^2 is termed the joint acceptance. The term was also used in the modal analysis portion of VIN (see equation 78). The methods used to calculate the joint acceptance in the low frequency regime still apply. In addition, empirical techniques can be used successfully as the modal density becomes great and SEA approximations become valid.

Two important assumptions can usually be made to significantly simplify the calculation of the net power into the cavity. The first is to assume weak coupling and the second is to neglect cross-acceptance terms. The following excerpt from the PACES analytical model presentation^(3, pp. 20-22) provides an excellent description and defense of these assumptions. Making these assumptions, equation 170 becomes

$$W_{rad}(\omega) = - \rho \omega^3 A^2 S_{pbl}(\omega) \sum_r |a_{rr}|^2 I_{rr}(\omega) J_{rr}^2(\omega) \quad (171)$$

where

$$|a_{rr}| = \frac{1}{\left(M_r Y_r(\omega) - \rho \omega^2 (J_{rr} + I_{rr}) \right)}$$

It is common, in the analysis of acoustic transmission from a structure to a cavity, to assume that the coupling is weak when the fluid in the cavity is gaseous. Under this assumption the coupling between structure and cavity can be calculated using the in vacuo panel resonance frequencies and the blocked, or rigid wall, resonant response of the cavity. Mathematically, this means that the power flow between a mode of the structure and a mode of the cavity can be evaluated without including the interaction of any other mode. The assumption of weak coupling will be made in the development of the present analytical model for the payload bay acoustics.

Having made this assumption, some justification should be provided. Unfortunately, this is difficult in general terms, although the results of Lyon and Maidanik⁽⁷⁾ provide at least a sufficient condition for weak coupling. The condition is

$$B_{rn} \ll \Delta\omega_r \text{ and } B_{rn} \ll \Delta\omega_n$$

where

$$B_{rn} = \left[\frac{c_o^2}{VM \gamma_r \gamma_n} \right]^{1/2} A L_{nr}$$

V is the volume of the cavity, M the total mass of the structure of area A, $\gamma_r = 1/4$ and $\gamma_n = 1/8, 1/4, 1/2$ or 1 depending on mode order. Also $\Delta\omega_r$ and $\Delta\omega_n$ are the structural and acoustic mode bandwidths respectively. The

function L_{nr} is the coupling factor between the structure and the cavity... [as defined in section 2, equation 25].

Applying this criterion to the Shuttle payload bay, it is seen that the criterion is not satisfied in the lowest frequency bands of interest. However, there are two additional factors to be considered. Firstly, effects of strong coupling will be important only when the structural mode is a volume-displacing mode. Such modes constitute only one-quarter of the structural modes; weak coupling can be assumed for the other three-quarters.

Secondly, there is evidence⁽⁸⁾ that strong coupling will be destroyed if there are air leaks in the cavity, and, in practice, the payload bay will not be airtight. Therefore, it appears that the assumption of weak coupling is reasonable for the acoustic model of the payload bay. In VIN this model is only used in the higher modal density regime where the weak coupling criteria are easily met.

It should be emphasized that the assumption of weak coupling, i.e., no acoustic coupling of structural modes, in no way excludes so-called well-coupled acoustic and structural modes, which occur^(7,9) when acoustic and structural modes have "maximum proximate mode coupling". That is, the resonance frequencies of the structural cavity modes are closely spaced relative to the modal bandwidths. The condition for well-coupled modes is variously written as⁽⁷⁾

$$|\omega_n^2 - \omega_r^2| < (\Delta\omega_n + \Delta\omega_r)$$

or⁽¹⁰⁾

$$2|\omega_n - \omega_r| < (\Delta\omega_n + \Delta\omega_r).$$

It is appropriate at this stage to include also a brief discussion of the cross-acceptance, since this also is a structure-fluid coupling function. Wilby⁽¹⁰⁾ has compared contributions from joint and cross acceptances for lightly damped rectangular panels exposed to either subsonic turbulent boundary layer or convected acoustic plane wave excitation. In almost all cases the cross acceptance contribution to the panel response power spectral density is negligible. This is true both at frequencies close to resonance frequencies and at frequencies away from resonances (the latter being the more critical condition). Thus, within the accuracy of the analytical model, cross acceptance terms can be neglected (i.e., $j_{tn}^2(\omega) \approx 0, t \neq n$).

3.2 Adaptation of Power Input Model to Statistical Energy Analysis Form

The previous section developed a modal analysis equation for the power radiated through the walls of a cavity from an external pressure field. It must now be modified into statistical form for use when the vehicle's acoustic modal density becomes large. As a first step in this modification, energy loss from the structure caused by interaction with the internal cavity air will be neglected ($\rho \omega^2 I_{rr} \approx 0$). Also, the structural energy loss caused by external acoustic radiation of energy will be combined with the structural damping loss factor η . Hence, realizing only the real power is of interest, the power radiated into the cavity is

$$W_{\text{rad}}(\omega) = \rho \omega^3 A^2 S_{\text{pbl}}(\omega) \sum_r \frac{I_m(I_{rr}(\omega)) J_{rr}^2(\omega)}{|M_r Y_r(\omega)|^2} \quad (172)$$

where $I_m(I_{rr}(\omega))$ is the imaginary part of $I_{rr}(\omega)$.

When the acoustic mode count within a band becomes sufficiently dense^(2, p. 41)

$$I_m(I_{rr}(\omega)) = R_r^{\text{int}}(\omega) / 4 \rho \omega \quad (173)$$

and since

$$R_r^{\text{int}}(\omega) = \frac{2}{\pi} \frac{\rho \omega^2}{C_o} A^2 J_r^{\text{int}}(\omega) \quad (174)$$

$$I_m(I_{rr}(\omega)) = \frac{A^2 \omega}{2 \pi C_o} J_r^{\text{int}}(\omega) \quad (175)$$

Substitute equation 175 into equation 172 along with

$$W_{\text{rad}}(\omega) = \frac{\rho A^4}{2 \pi C_o} S_{\text{pbl}}(\omega) \sum_r \frac{J_r^2(\omega) J_r^{\text{int}}(\omega)}{M_r^2} \cdot \frac{\omega^4}{|Y_r(\omega)|^2} \quad (176)$$

The internal joint acceptance, $J_r^{2\text{int}}(\omega)$, the coupling of the motion of the structure with the internal pressure at the structural/acoustical interface, is equal to the joint acceptance with a reverberant field in the higher frequency range.

The power flowing through the wall structure into the cavity in the band $\Delta\omega$ with center frequency ω_c is, therefore,

$$\int_{\omega_1}^{\omega_2} W_{\text{rad}}(\omega) d\omega = \frac{\rho A^4}{2\pi C_0} \cdot \left[S_{\text{pbl}}(\omega_c) \sum_r \frac{J_r^2(\omega_c) J_r^{2\text{rev}}(\omega_c)}{M_r^2} \cdot \int_{\omega_1}^{\omega_2} \frac{\omega^4}{|Y_r|^2} d\omega \right] \quad (177)$$

where

$S_{\text{pbl}}(\omega_c)$, $J_r^2(\omega_c)$, and $J_r^{2\text{rev}}(\omega_c)$ are all assumed to vary slowly over the band.

The solution to equation 177 can be broken down into the summation over three types of structural modes: those modes resonant below the band, those resonant in the band, and those resonant above the band. Once the structural modal density becomes relatively high, those modes above the band can be neglected with little adverse effect on accuracy. Hence,

$$W_{\text{rad}} = W_{\text{rad}}^{\text{nr}} + W_{\text{rad}}^{\text{res}} \quad (178)$$

$W_{\text{rad}}^{\text{nr}}$ is power from modes resonant below the band

$W_{\text{rad}}^{\text{res}}$ is the power from modes resonant in the band

$$W_{\text{rad}}^{\text{nr}} = S_{\text{pbl}}(\omega_c) \cdot \frac{\rho A^4}{2\pi C_0} \sum_{r < \text{band}} \frac{J_r^2(\omega_c) J_r^{2\text{rev}}(\omega_c)}{M_r^2} \cdot \int_{\omega_1}^{\omega_2} \frac{\omega^4}{|Y_r(\omega)|^2} d\omega \quad (179)$$

$$W_{\text{rad}}^{\text{res}} = \frac{\rho A^4}{2\pi C_0} \left[S_{\text{pbl}}(\omega_c) \cdot n_r \cdot \left\langle \frac{J_r^2(\omega_c) J_r^{2\text{rev}}(\omega_c)}{M_r^2} \right\rangle_r \cdot \int_{\omega_1}^{\omega_2} \frac{\omega^4}{|Y_r(\omega)|^2} d\omega \right] \quad (180)$$

where

$\langle \rangle_r$ denotes average values of the enclosed terms over the band of interest

n_r is the structural modal density in the band of interest

Evaluation of the integrals over frequency in equation 179 is carried out analytically in the same way as the identical integral in section 2, equation 82. The integrals over frequency in equation 180 can be estimated by

$$\int_{\omega_1}^{\omega_2} \frac{\omega^4}{|Y_r(\omega)|^2} d\omega \simeq \int_{-\infty}^{\infty} \frac{\omega^4}{|Y_r(\omega)|^2} d\omega \simeq \frac{\pi \omega_c}{2\eta} \quad (181)$$

The band-limited external power input to cavity k of a multiple cavity system can be estimated with the equation

$$\begin{aligned}
 W(k) = & \sum_s \left[S_{pbl}(\omega_c) \cdot \frac{\rho A^4}{2\pi C_o} \cdot \sum_{r < \text{band}} \frac{J_r^2(\omega_c) J_r^{2rev}(\omega_c)}{M_r^2} \right. \\
 & \cdot \int_{\omega_1}^{\omega_2} \frac{\omega^4}{|Y_r(\omega)|^2} d\omega + S_{pbl}(\omega_c) \cdot \frac{\rho A^4}{2\pi C_o} \\
 & \cdot n_r \cdot \left. \left\langle \frac{J_r^2(\omega_c) J_r^{2rev}(\omega_c)}{M_r^2} \right\rangle_r \cdot \frac{\pi \omega_c}{2\eta} \right]_{\text{surface } s} \quad (182)
 \end{aligned}$$

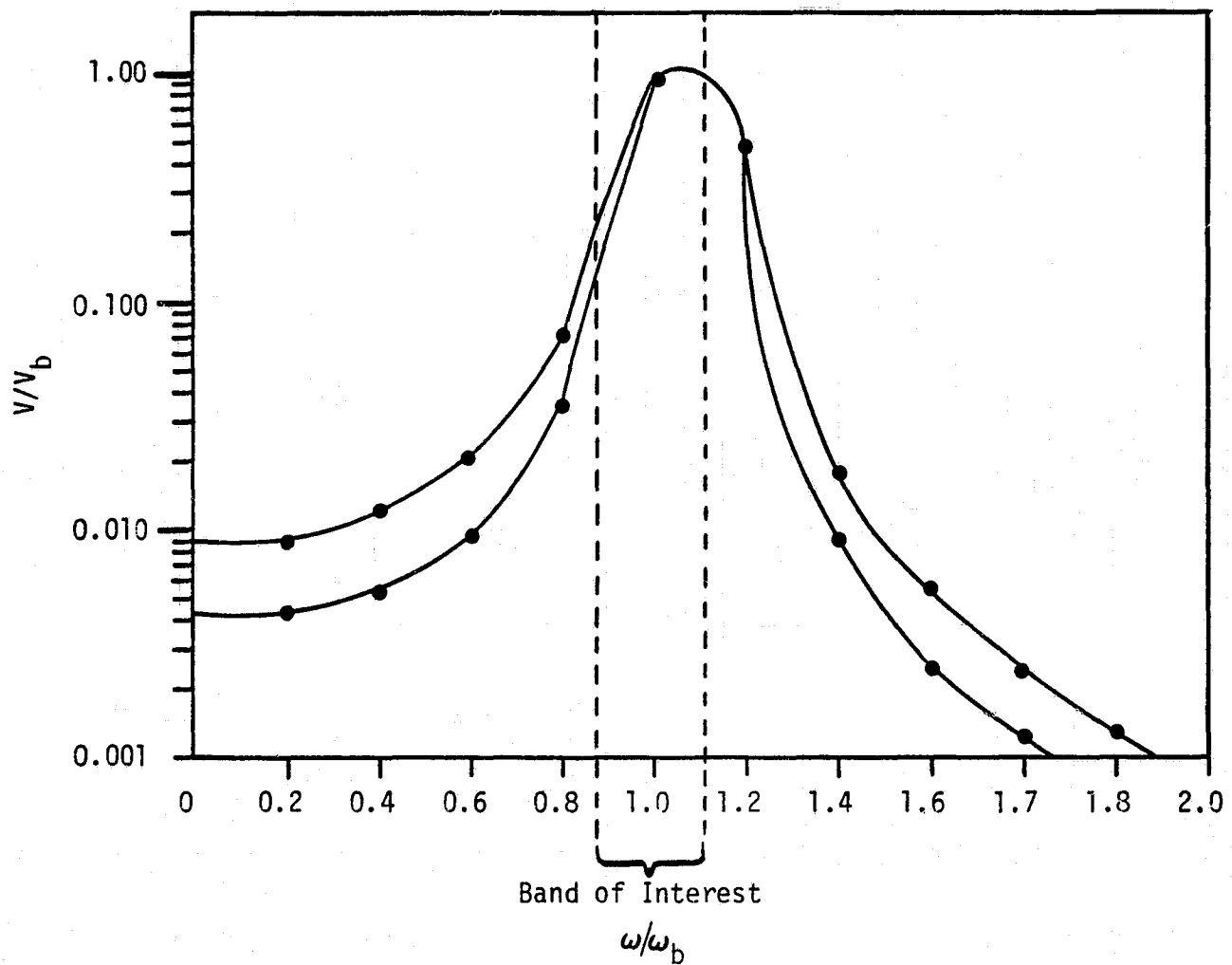
where

s is adjacent to the volume k

$\bar{W}(k)$ is the system external power into cavity k of a multiple cavity system

The relative significance of the input power from a nonresonant mode decreases rapidly the further the nonresonant mode is from the band of interest. Figure 1 clearly demonstrates this fact. If two or more modes occur within the band of interest, the modes occurring outside the band will provide relatively little to the overall sum. At most, the modes in the two previous bands will be of importance if the number of structural modes in the band of interest are sufficient for SEA approximations. Hence, the power input from modes not resonant in the band can be estimated by

$$\begin{aligned}
 W_{rad}^{nr} \approx & \sum_{b=(\text{band}-2)}^{\text{band}} \frac{\rho A^4}{2\pi C_o} \cdot S_{pbl}(\omega_c) \cdot n_b \\
 & \cdot \left\langle \frac{J_b^2(\omega_c) J_b^{2rev}(\omega_c)}{M_b^2} \right\rangle_b \cdot \int_{\omega_1}^{\omega_2} \frac{\omega^4}{|Y_b(\omega)|^2} d\omega \quad (183)
 \end{aligned}$$



where ω/ω_b - ratio of the modal natural frequency to the center frequency of the band of interest.

V/V_b - ratio of the intergral over the band of interest of a mode at ω/ω_b to the intergral over the band of interest of a mode at the center frequency of the band of interest.

Figure 1. Modal Contribution to the Band of Interest

where

b is index designating the band containing the "nonresonant" modes

ω_c is the center frequency of the band of interest, r

n_b is the modal density in the band b below the band of interest

$|Y_b(\omega)|^2$ is the typical response characteristic of a mode in band b .

$\langle \rangle_b$ is the average value of the bracketed terms in the band b

The final equation for the system external power input into volume K of a multiple cavity (and multiple surface) system becomes (substitute equation 183 into 182)

$$\begin{aligned}
 W(K) = & \sum_s \left[S_{pbl}(\omega_c) \cdot \left(\frac{\rho A^4}{2\pi C_o} \sum_{b=(band-2)}^{band} n_b \right. \right. \\
 & \cdot \left\langle \frac{J_b^2(\omega_c) J_b^{2rev}(\omega_c)}{M_b^2} \right\rangle_b \cdot \int_{\omega_1}^{\omega_2} \frac{\omega^4}{|Y_b(\omega)|^2} d\omega \\
 & \left. + \frac{\rho A^4}{2\pi C_o} \cdot n_r \cdot \left\langle \frac{J_r^2(\omega_c) J_r^{2rev}(\omega_c)}{M_r^2} \right\rangle_r \cdot \frac{\pi \omega_c}{2\eta} \right]_{\text{surface } s} \quad (184)
 \end{aligned}$$

Often, semiempirical methods are used to estimate the joint acceptance for various external pressure field/surface element-type combinations. When this is done, estimations for $J_b^2(\omega_c)$ are seldom available. $J_b^2(\omega_c)$, then, must be approximated by $J_b^2(\omega_b)$, where ω_b is the center frequency of band b . If the exterior pressure field magnitude is expressed in terms of band-limited mean-square pressure, the $S_{pbl}(\omega_c)$ is replaced in equation 184 by the band level divided by the bandwidth.

3.3 Power Dissipation from the Cavity

The previous two sections developed equations for the calculation of the system external power transfer through the structural walls into the cavity (the input power matrix $\{W\}$). This section will develop the SEA expressions for the power transferred from or dissipated in the cavity. Power can be dissipated from a cavity through (1) the structural walls adjacent to the cavity; (2) openings to adjacent cavities--this may be a positive or negative; that is, power can also flow into the cavity through openings--(3) absorption of power by the cavity wall surfaces. Expressions for each of these modes of power "dissipation" will be developed for use in the power balance equation and will form the coefficient matrix, $[C]$.

Expanding on the introduction, define

$$C(k, k) = \sum_j C_j(k, k) + C_a(k, k) + \sum_l C_l(k, k) \quad (185)$$

$$C(k, i) = \sum_l C_l(k, i)$$

where

$C_j(k, k)$ - Coefficient for power transferred out of cavity k through wall j of the cavity

$C_a(k, k)$ - Coefficient for power absorbed in cavity k by the surfaces of the cavity

$\sum_l C_l(k, k)$ - Coefficient for power transmitted from cavity k to an adjacent cavity through opening l

$\sum_l C_l(k, i)$ - Coefficient for power transmitted from cavity i to cavity k through opening l

3.3.1 Power Transferred from the Cavity Through the Structural Walls

Outward transmission of power through a structural wall is simply the reverse of the input power process.

$$W_{out} = \pi A^2 n_r \left\langle \frac{J_r^{2rev}(\omega_c)}{M_r} \right\rangle_r \quad (186)$$

assuming the internal joint acceptance approaches the joint acceptance for reverberant excitation and the power transferred out of the volume due to nonresonant modes is negligible in the SEA regime.

The total power transferred out through the structural walls j of cavity k is a linear summation over all walls adjacent to the cavity.

$$\sum_j C_{j(k,k)} = \sum_j \left[\pi A^2 n_r \left\langle \frac{J_r^{2rev}(\omega_c)}{M_r} \right\rangle_r \right]_{\text{surface } j} \quad (187)$$

3.3.2 Power Transferred Through the Openings of the Cavity

A very rough estimate of the power transmitted through the openings in a cavity to or from other cavities of the multiple cavity system can be obtained using Green's function concepts and requiring the pressure at the opening between cavities to be equal. The conductance of an opening is defined as

$$\Gamma = \rho C_o A \operatorname{Re} \left\{ \left(\int_0 \left(P_n(x_o) / V_n(x_o) \right) dx_o \right)^{-1} \right\} \quad (188)$$

where

$V_n(x_o)$ is the particle velocity at A due to mode n of volume 1

$P_n(x_o)$ is the particle pressure at A due to mode n of volume 1

Pressure is calculated from the Green's function by^(4, p. 375)

$$\begin{aligned} p(x_o) &= i\omega\rho \int_{x_o} G_1(x_o|x'_o) V_n(x'_o) dx'_o \\ &= -i\omega\rho \int_{x_o} G_2(x_o|x'_o) V_n(x'_o) dx'_o \end{aligned} \quad (189)$$

where

G_1 and G_2 are the Green's functions of the cavities connected by the opening
 $V(x'_o)$ is an imposed velocity at the opening

Let $G'_1(x_o|x'_o)$ be $G_1(x_o|x'_o)$ with the n -th term deleted. Then from equation 141,

$$G'_1(x_o|x'_o) = \sum_{m \neq n} \frac{\psi_m(x_o) \psi_m(x'_o)}{M_m Y_m(\omega)}$$

Hence,

$$i\omega\rho \int_{x_o} G_1(x_o|x'_o) V_m(x_o) dx_o = P_n(x'_o) + ik\rho C_o \int_{x_o} G'_1(x_o|x'_o) V_n(x_o) dx_o$$

Solving for $P_n(x'_o)$

$$P_n(x'_o) = -i\omega\rho \int_{x_o} G'_1(x_o|x'_o) G_1(x_o|x'_o) V_n(x_o) dx_o \quad (190)$$

Substitute equation 190 into 188.

$$\begin{aligned} \Gamma &= \rho C_o A \operatorname{Re} \left\{ -i\omega\rho \int_{x_o} \int_{x'_o} \left((G'_1(x'_o|x_o) + G_2(x'_o|x_o)) \right. \right. \\ &\quad \left. \left. \cdot \left(V_n(x_o)/V_n(x'_o) \right) dx_o dx'_o \right)^{-1} \right\} \end{aligned} \quad (191)$$

Assuming $V_n(x_0) = V_n(x'_0) = \text{constant}$ and that the subvolumes have sufficiently large wall losses, Morse and Ingard⁽⁴⁾ state

$$-i\omega\rho \int_{x_0} \int_{x'_0} \left(G'_1(x'_0|x_0) + G'_2(x'_0|x_0) dx_0 \right) dx'_0 \approx 2Z_c \quad (192)$$

where Z_c is the impedance of a baffled plane piston of area A radiating into two half spaces and is

$$Z_c = (\theta - i\chi)A\rho C_0 \quad (193)$$

This yields

$$\Gamma = \rho C_0 A \operatorname{Re} \left[(2Z_c)^{-1} \right] = \frac{\theta}{2(\theta^2 + \chi^2)} \quad (194)$$

where

θ is the normalized reactance of the opening
and χ is the normalized resistance of the opening

The power transferred through the opening can be calculated by

$$W_c = \frac{A}{2\rho C_0} \int_{x_0} \frac{\theta}{(\theta^2 + \chi^2)} \cdot p(x_0) dx_0 \quad (195)$$

where $p(x_0)$ is the pressure at the opening and A is the area of the opening.

In the high frequency, high modal density regime, SEA approximations along with the above developments to yield

$$W_c = \frac{A}{2\rho C_0} \frac{\theta}{(\theta^2 + \chi^2)} \cdot T \cdot \left(\langle p_1^2 \rangle - \langle p_2^2 \rangle \right) \quad (196)$$

Where $\langle p_1^2 \rangle$ and $\langle p_2^2 \rangle$ are the space-averaged band-averaged pressure in cavities 1 and 2 respectively and $T \approx 1/2$ given the case of many oblique modes. Hence, for the high frequency regime where there are many oblique modes,

$$C_\ell(k, k) = \frac{A_\ell}{4\rho C_0} \left(\frac{\theta_\ell}{(\theta_\ell^2 + \chi_\ell^2)} \right) \quad (197)$$

$$\text{and } C_\ell(k, i) = - \frac{A_\ell}{4\rho C_0} \left(\frac{\theta_\ell}{(\theta_\ell^2 + \chi_\ell^2)} \right)$$

ℓ - is opening number

A_ℓ - area of opening ℓ

θ_ℓ - normalized resistance of opening ℓ

χ_ℓ^2 - normalized reactance of opening ℓ

Estimates for the conductance are only available for simple opening geometries. When the acoustic wavelength is short compared to the opening size, the conductance is somewhat shape independent and primarily a function of total area. The openings should offer very little resistance to the flow of acoustic power between subvolumes. The important aspect of the conductance estimate is that the relative resistances of the several cavity openings are roughly estimated. This defines the distribution of acoustic power between the subvolumes.

3.3.3 Power Absorbed by the Walls of the Cavity

The power absorbed by the walls of the cavity is an extremely important part of the SEA calculations. The inaccuracies associated with the calculation of this term can far outweigh the effects of all other SEA approximations combined. The power absorbed by the walls of the cavity is

$$W_{\text{abs}} = \frac{1}{2\rho C_0} \sum_{\ell} A_\ell \langle p_\ell^2 \rangle_A \epsilon_\ell \quad (198)$$

where

A_l is the area of surface

ϵ_l is the conductance of surface

$\langle P_l^2 \rangle$ is twice the band-limited mean square pressure averaged over the surface

Assume

$$\langle P_l^2 \rangle_A \approx \langle P_k^2 \rangle_{\text{volume}} \cdot 4$$

where $\langle P_k^2 \rangle$ is the space-averaged, band-limited pressure over volume k.

Then

$$W_{\text{abs}} = \frac{2}{\rho C_o} \sum A_l \langle P_k^2 \rangle \epsilon_l \quad (199)$$

where all surfaces, l , are adjacent to volume k.

In the high frequency regime where the modal density is great,

$$\epsilon_l \approx \alpha_l / 8$$

Substituting

$$W_{\text{abs}} = \frac{1}{4\rho C_o} \sum_l \alpha_l A_l \langle P_k^2 \rangle \quad (200)$$

Hence,

$$C_a(k, k) = \frac{1}{4\rho C_o} \sum_l \alpha_l A_l \quad (201)$$

where α is the band-limited random absorption coefficient of wall l and wall l bounds cavity k.

Section 4

COMPUTER PROGRAM

The computer program VIN implements the modal and statistical energy analysis methods presented in sections 2 and 3 in user-oriented, general purpose form. The two analysis methods are functionally separate techniques. The modal analysis portion of the program can provide both discrete frequency and band average estimates of a vehicle's interior pressure given the external excitation of the vehicle structure. While the technique is theoretically valid over any frequency range, the number of structural and acoustic modes required to obtain acceptable accuracy can become computationally prohibitive as modal densities increase with frequency. Band-averaged, space-averaged estimates of the vehicle interior pressure can be obtained with statistical energy analysis when the modal density becomes sufficient to justify the technique's assumptions. The program is structured to allow an easy transition between the methods during a single computer run with the geometry definition methodology as the "common connecting ground."

The vehicle structure can be represented by any number of "elements" with known user-supplied, in vacuo response characteristics. The user may describe each element's response characteristics in the coordinate system and orientation best suited for that particular structure. The acoustic modal response characteristics of the vehicle's interior space can be calculated by the program from user-supplied hardwall acoustic response characteristics of smaller, simpler cavity shapes that approximate the vehicle's interior space. The method utilized, acoustic component mode synthesis, is described in mathematical detail in section 2. When the acoustic modal density is sufficient to justify the SEA assumptions, detailed acoustic response characteristics are no longer required and reverberant acoustics are assumed. The user must also define the external acoustic field on the vehicle and make various program option selections.

In section 4, the organization and structure of VIN is documented. The nuts and bolts of the program's use is described in section 6, "Computer User's Manual."

4.1 General Overview

The key routines of the program VIN are outlined below. The routines are first called during execution of the program in the order in which they appear in the outline. The program is segmented so that only those routines needed for each particular stage of the problem solution are held in core memory. The core data storage requirements are a function of the specific problem size and the options selected by the user. The program code is in ASCII Fortran (LEVEL 10R1). A random access mass storage device and line printer are the only required peripherals.

VIN

PART I. Program Initiation and Control

1. MAIN
2. DATALD

PART II. Modal Analysis

1. FRQCAL
2. BND CAL
3. MULPRM
4. MULCV
5. PRMCAL
 - a. GERMAS
 - b. LNM CAL
 - c. ZANCAL
 - d. RJACAL
 - e. MODES
6. MDLPRM
7. CALC
8. DFCALC
9. REVERB

PART III. Statistical Energy Analysis

1. HFREQ
 - a. CBJAL

- b. CJA
 - c. WMAT
 - d. CMAT
- 2. SEAPRM
 - 3. SEARES

PART I. Program Initialization and Control

1. MAIN

MAIN sets up the required mass storage files and dynamically allocates array storage based on the current problem size given by the input data. The routine also controls the flow of the program calculations. It resides in core memory throughout the execution of the program.

Since the program dynamically allocates the array storage based on input data, core storage is always efficiently used regardless of the problem size. Dimension statements do not limit the problem size or complexity in any way.

2. DATALD

DATALD reads all the required input data from a specified data file, data cards, or mass storage files. The input is fully mirrored to a user-selected output device. Some diagnostics are provided to flag gross input errors. The coordinate transformation matrices, which fix the location of the structural and acoustic elements in global space, are calculated. Any new finite element data to be used to define an element's response characteristics is loaded and converted into two-dimensional fourier series form in DATALD.

The input data establishes which program calculation and/or data manipulation options are desired. The input also defines the structural and acoustic geometry and response characteristics along with the external pressure field excitation.

PART II. Modal Analysis

1. FRQCAL

FRQCAL is a group of routines that calculate the natural frequencies of the volume, opening, and surface elements that are included in the program's library of modal elements.

2. BNDCAL

BNDCAL calculates the modal summation bandwidths, BANDWN and BANDWM, as described in section 2.2.5. These bandwidths are used to limit program calculations at each band of interest to only those structural and acoustic modes of significant importance to the overall results in that band.

3. MULPRM

MULPRM calculates the parameters required for the acoustic component mode synthesis that is carried out in MULCV.

4. MULCV

MULCV calculates the modal response characteristics of acoustic spaces of complex shape from the known response characteristics of simpler shapes combined to approximate the complex shape. The acoustic component mode synthesis performed in MULVC is fully described in section 2.2.1.

5. PRMCAL

PRMCAL is actually a group of routines that either calculate or direct the calculation of the parameters needed for modal analysis of a complex cavity shape with multiple structural walls. These routines are

- a. GENMAS. GENMAS calculates the generalized acoustic mass of a cavity whose modes were obtained through component mode synthesis.
- b. LNMAL. LNMAL calculates the structural/acoustic coupling coefficients, LNM for those structural and acoustic modal combinations that are important to the problem solution.

c. ZANCAL. ZANCAL calculates the cavity acoustic damping from the cavity modal response and each wall's normal absorption coefficient.

d. RJACAL. RJACAL calculates the joint acceptance of a given external excitation field with the modes of the structure for each frequency band in which the structural mode has a significant response.

e. MODES. Modes is a group of routines, accessed by PRMCAL, that provides acoustic, opening, and structural mode shape information. The information is organized in the form of a program library of modal elements. This program code held library provides both geometric and modal response descriptions. MODES also contains routines for the numeric and/or analytical surface integrations required to calculate the modal analysis parameters.

6. MDLPRM

MDLPRM outputs to paper the program calculated parameters used in the modal analysis portion of the program.

7. CALC

CALC calculates the interior pressure of the cavity in two forms: space-averaged, band-averaged pressure squared (SABAP) over each subvolume of the cavity and the SABAP over the entire multiple cavity system. The external excitation can be random or deterministic but must be described in the frequency domain.

8. DFCALC

DFCALC calculates the interior space-averaged pressure at discrete frequencies. The external excitation can be random or deterministic but must be described in the frequency domain.

9. REVERB

REVERB estimates the reverberation time of complex shaped cavities with arbitrary surface absorption characteristics. The fundamental parameters used in the estimation are calculated in PRMCAL.

PART III. Statistical Energy Analysis

1. HFREQ

HFREQ calculates the space-averaged, band-averaged pressure squared over each subvolume of an arbitrarily shaped cavity. The external excitation must be random. A brief description of the technique and the assumptions implicit in its use are given in section 6.3. A collection of routines is needed to assemble the SEA band-averaged power balance equations. The equations are solved for each band of interest.

a. CBJAL. CBJAL calculates the band-averaged joint acceptance for the modes resonant below the band of interest for each surface exposed to external excitation..

b. CJA. CJA calculates the band-averaged joint acceptance of the modes resonant in the band of interest for each surface exposed to the external excitation.

c. WMAT. WMAT prepares the input power matrix for the power balance equations.

d. CMAT. CMAT is a group of routines that prepares the matrix representing the power dissipation mechanisms of the SEA system. This includes power transferred between subvolumes of the cavity, power absorbed by the cavity walls, and power transferred out of the system through the walls of the cavity.

2. SEAPRM

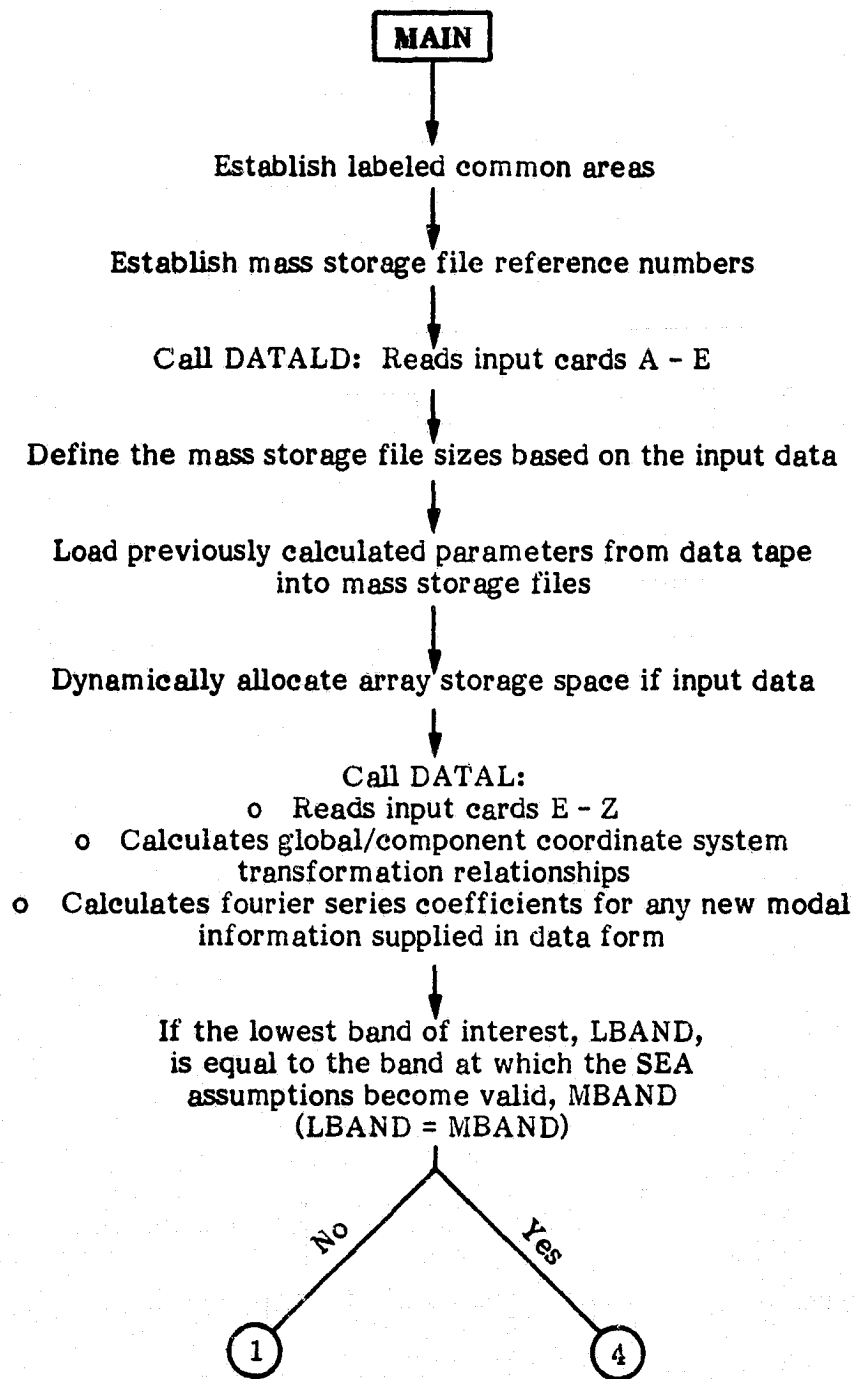
SEAPRM outputs to paper the program calculated parameters used in the SEA portion of the program.

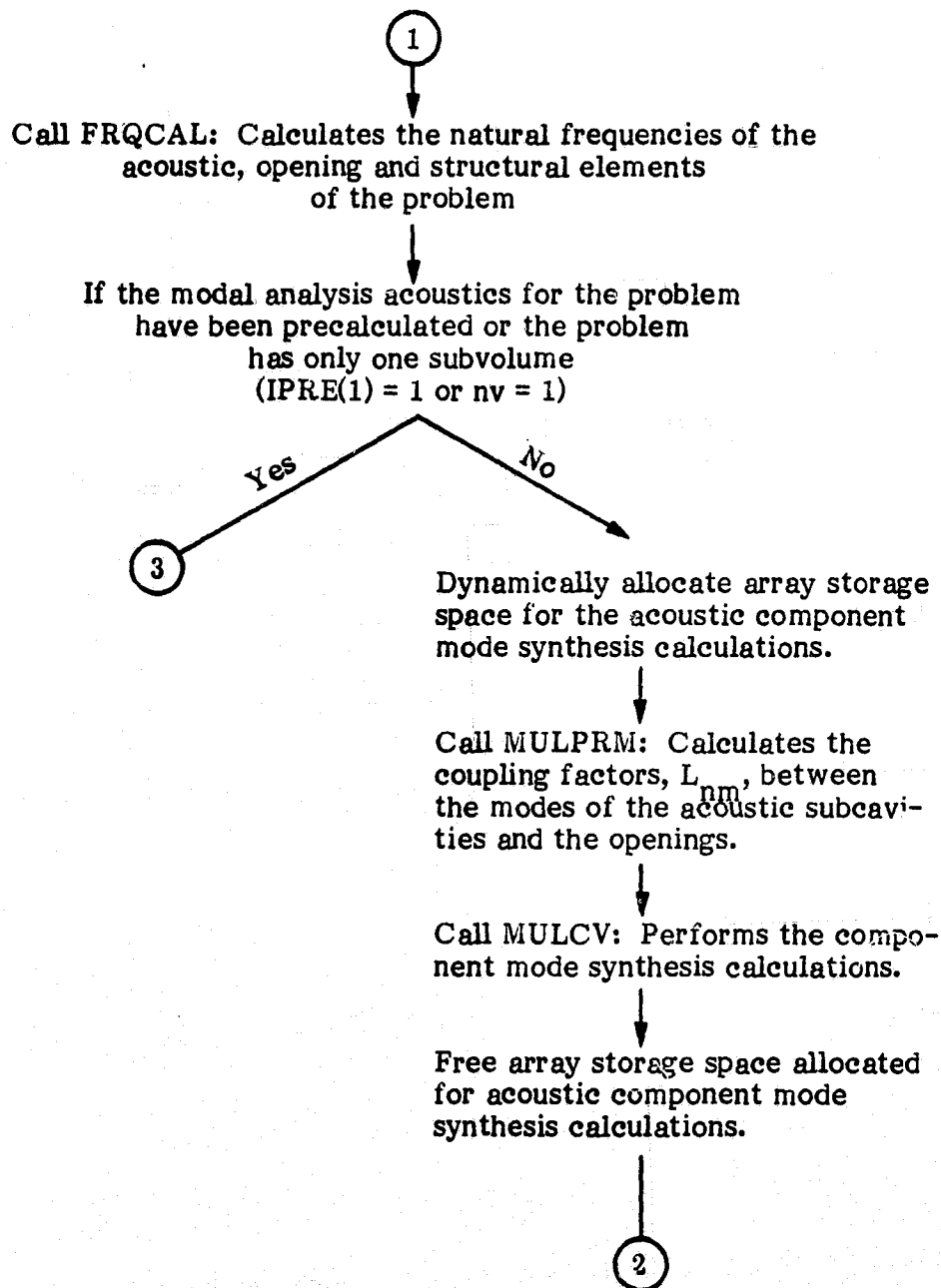
3. SEARES

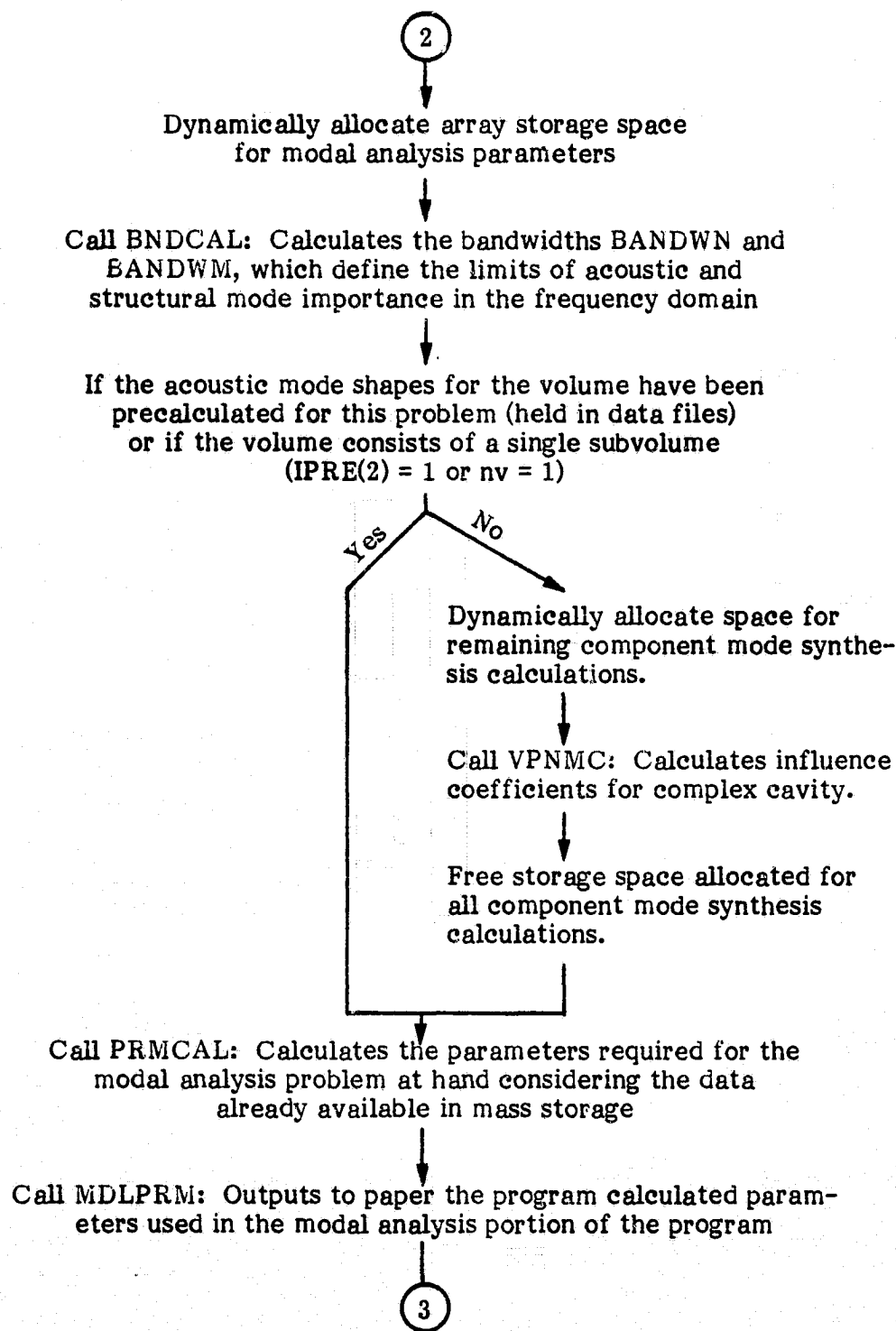
SEARES outputs the results of the SEA portion of the program calculations.

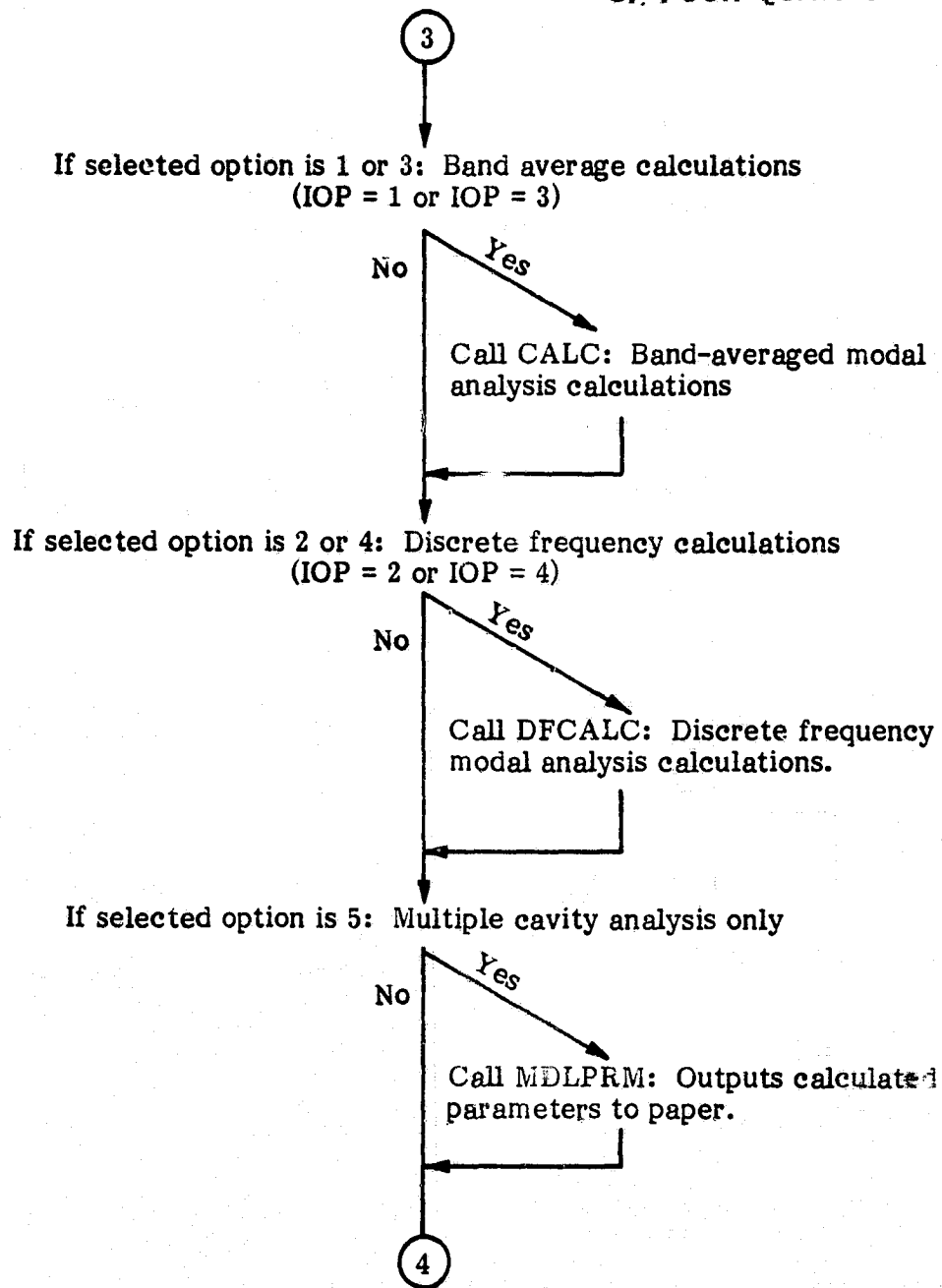
4.2 Flowchart

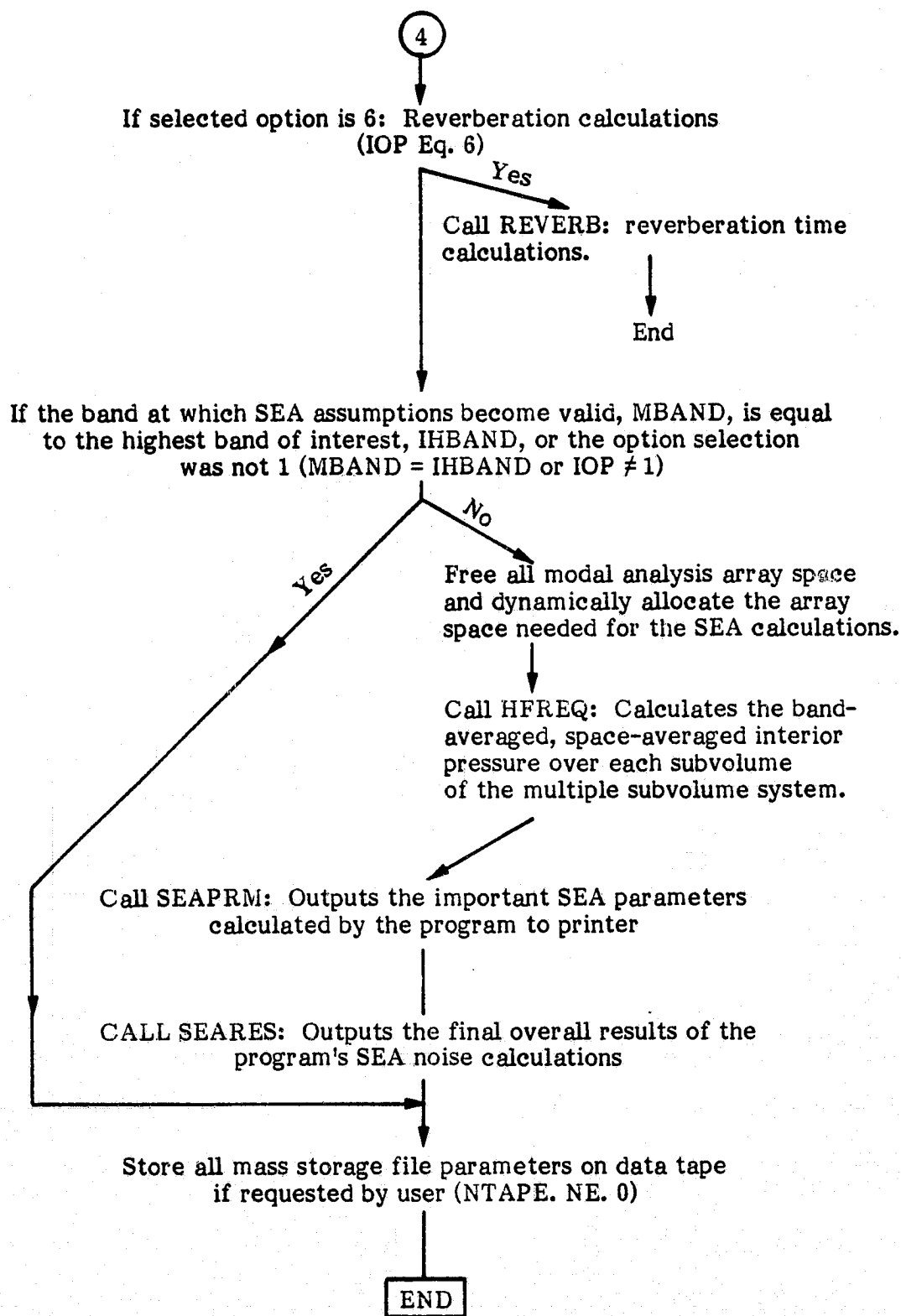
The program MAIN, which directs the flow of VIN's computations, is charted in this section. In section 6, detailed information is provided about the routines that the user may desire to access and update (structural and acoustic geometry definitions, response definitions, and surface integrations). The remainder of the routines should be considered black boxes--not to be tampered with. Nevertheless, the program code is commented throughout for basic documentation purposes.











Section 5

COMPUTER PROGRAM VERIFICATION

The modal and SEA analytical models, as implemented in the computer program VIN, were verified by the following series of test cases:

1. Acoustic component mode synthesis
2. Modal analysis parameter calculations
3. Modal analysis noise predictions
4. Statistical energy analysis noise predictions

The results of each step are discussed in turn. The application of the program to the very complex Space Shuttle payload bay problem is given in section 7 with comparisons to both on ground experiment and flight data. As will be further discussed later, the complexity of the Space Shuttle structure and flight environments make it a poor test case for the evaluation of basic analytical and computer methodology. The input data for each test case is given in appendix E.

5.1 Verification of Acoustic Component Mode Synthesis

The modes and mode shapes of a rectangular cavity with a partial partition were calculated to exercise the component mode synthesis capability of the program. The results were compared with experiment as recorded in the literature.⁽¹¹⁾ The cavity is illustrated in figure 2. The error in acoustic modal frequency over the first dozen

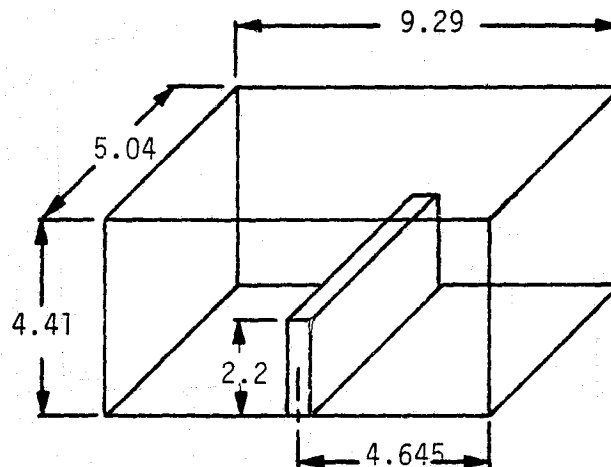


FIGURE 2. Acoustic Component Mode Synthesis Two-Cavity Test Case

modes is given in table 1 as a function of various modal retention parameters. Analysis of mode shape accuracy is germane in this model only in the context of surface integrations. Component mode synthesis determined mode shapes are discussed in this regard in the next section.

To exercise the program's ability to handle more than two subvolumes, the cavity was divided into three subcavities, as illustrated in figure 3. The results, given in table 2, complete the verification of the calculation methodology and computer implementation of the acoustic component mode synthesis.

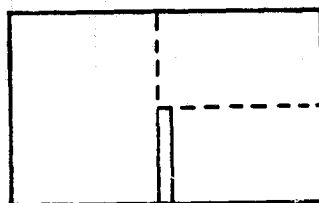


FIGURE 3. Acoustic Component Mode Synthesis
Three-Cavity Test Case

5.2 Verification of Modal Analysis Parameter Calculations

Each modal analysis computational option uses the same basic parameters to describe the system. These parameters are calculated in the routines GENMAS, LNMAL, ZANCAL, RJACAL, QMWBCAL, (see section 4.1 under PRMCAL). The calculation of GENMAS (the generalized acoustic mass of the multiple cavity system), LNMAL (the structural/acoustical coupling coefficient), and ZANCAL (the acoustic damping of the cavity) each involve, among other factors, a surface integration and the results of the acoustic component mode synthesis. Given a correct integration technique, the accuracy of each is a function of the component mode synthesis approximation of the acoustic multiple cavity mode shape:

$$F_n(x_o) = \sum_{n'} \frac{P_{n'}^v(\omega_n) F_{n'}^v(x_o)}{M_{n'}^a}$$

TABLE 1. COMPONENT MODE SYNTHESIS: TWO CAVITY RESULTS

Mode	VIN-A (Hz)	VIN-B (Hz)	Finite Element Analysis (4 elements) (Hz)	Measured Frequency (Hz)
1, 0, 0	668	672	635	570
0, 1, 0	1330	1330	1377	1330
1, 1, 0	1443	1442	1365	1448
2, 0, 0	1494	1474	1625	1470
0, 0, 1	1522	1536	1550	1534
1, 0, 1	1571	1551	1615	1555
3, 0, 0	1909	1869	2080	1840
2, 1, 0	1970	1963	2100	1980
0, 1, 1	2018	2089	1942	2036
2, 0, 1	2059	2293	2242	2120
2, 1, 1	2095	2436	2910	2500
Average Error (%)	1.96	2.4	4.5	

*VIN calculation with 5 opening modes retained.

**VIN calculation with 10 opening modes retained.

TABLE 2. COMPONENT MODE SYNTHESIS: THREE-CAVITY RESULTS

Mode	VIN-A (Hz)	VIN-B (Hz)	Finite Element Analysis (5 elements) (Hz)	Measured Frequency (Hz)
1, 0, 0	587	569	591	570
0, 1, 0	1296	1296	1346	1330
1, 1, 0	1453	1452	1470	1448
2, 0, 0	1474	1474	1630	1470
0, 0, 1	1518	1570	1550	1534
1, 0, 1	1572	1646	1597	1555
3, 0, 0	1862	1884	2043	1840
2, 1, 0	1929	1926	2116	1980
0, 1, 1	1987	1985	2041	2036
2, 0, 1	2017	2018	2255	2120
Average Error (%)	1.96	2.4	4.5	

*VIN calculation with 5 opening modes retained.

**VIN calculation with 10 opening modes retained.

where $F_{n'}^v(x_o)$ is the hard wall acoustic mode shape of the subcavity, v.
 $M_{n'}^a$ is the generalized mass of the subcavity v for the mode n'.
 $P_{v'}^v(\omega_n)$ is the multiple factor of constraint that relates subcavity mode shapes to the multiple cavity mode shape at the natural frequency, ω_n .

The accuracy of the component mode synthesis for a given problem is solely a function of the number of opening and acoustic modes retained in the analysis. The higher the natural frequency of the multiple cavity, the more modes, of both opening and subvolume, are required. A banding technique is used to reduce the modal retention requirements. The acoustic modes nearest the natural frequency being calculated are retained. The opening modes that couple well with the subvolume acoustic modes being used are also selected. Since other factors, such as the complexity of the multiple cavity system, the number of openings, the shape of the openings, also have an impact on the number of modes required for a given accuracy, important problems should be repeated with increasing modal retention (opening and acoustic modes) until the solution is shown to converge.

The mode shape accuracy is integrally connected with and directly related to the accuracy of the natural frequency calculations as presented in the previous sections. P_n^v is derived directly from the matrix that determines the natural frequency.

RJACAL requires integrations of the structural mode shape and the external pressure field over a surface. The program uses both analytic expressions and Gaussian quadrature for the integrations. The two types of calculations were checked against each other. The integration precision is easily within the accuracy of the analytic descriptions of the external pressure fields and of the structure's mode shapes.

5.3 Verification of Modal Analysis Noise Predictions

The previous section demonstrated that the acoustics of a cavity of complex shape can be estimated with component mode synthesis. This section shows that the modal analysis equations and methodology as implemented in VIN provides adequate noise predictions given correct structural and acoustic response data. In this regard, simple test cases with little latitude for input data inaccuracies provide the clearest

verification. Since the accuracy of the component mode synthesis calculations were tested, as reported in section 5.2, the remainder of the modal analysis calculations can be verified with a single cavity test case.

5.3.1 Modal Analysis With Random Excitation

An experiment with fairly well-defined structural and acoustic characteristics was selected from the literature.⁽¹²⁾ The test configuration is shown in figure 4. The one-third octave band results are compared with the predicted levels in figure 5. The program's discrete frequency calculation results are given in figure 6.

5.3.2 Modal Analysis With Deterministic Excitation

The only difference between the random and deterministic options is in the calculation of the generalized force over the transmission surfaces of the enclosure. All other portions of the calculations are shared. Since the accuracy of the generalized force calculations was tested in section 5.2, the test cases for random excitation also verify the modal analysis options with deterministic excitation (see section 5.3.1).

5.4 Verification of SEA Noise Predictions

Because of its very nature, statistical energy analysis can only be used given some form of random excitation. As previously presented in detail, the SEA model implemented in VIN is a modified form of the PACES model⁽⁴⁾ and provides space-averaged noise estimates for each of several interconnected cavities.

All but one aspect of the SEA power balance equations can be tested with a simple single-cavity test case. The excluded aspect is the power flow that occurs through the openings between cavities in multiple cavity cases.

A simple single-cavity experiment was chosen from the literature to exercise the bulk of the SEA computations. In this experiment⁽¹³⁾ a common 55-gallon oil drum was hung in a reverberation room. One-third-octave band noise reduction was measured over the range of 125 to 12,500 Hz. A comparison of SEA calculations to experimental results is shown in figure 7. The results are well within the usual accuracy of SEA estimates.

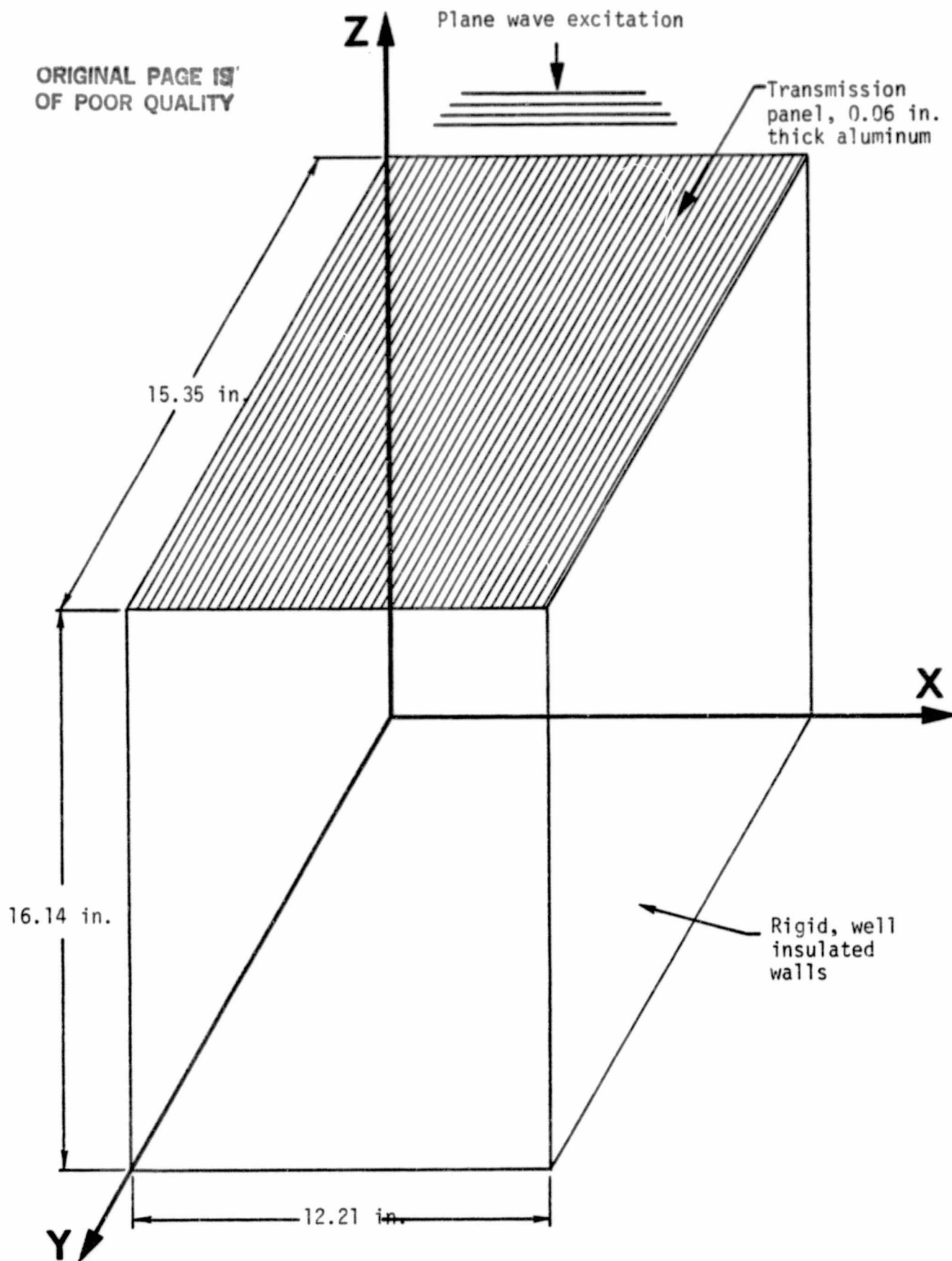


Figure 4. Modal Analysis Test Case Configuration

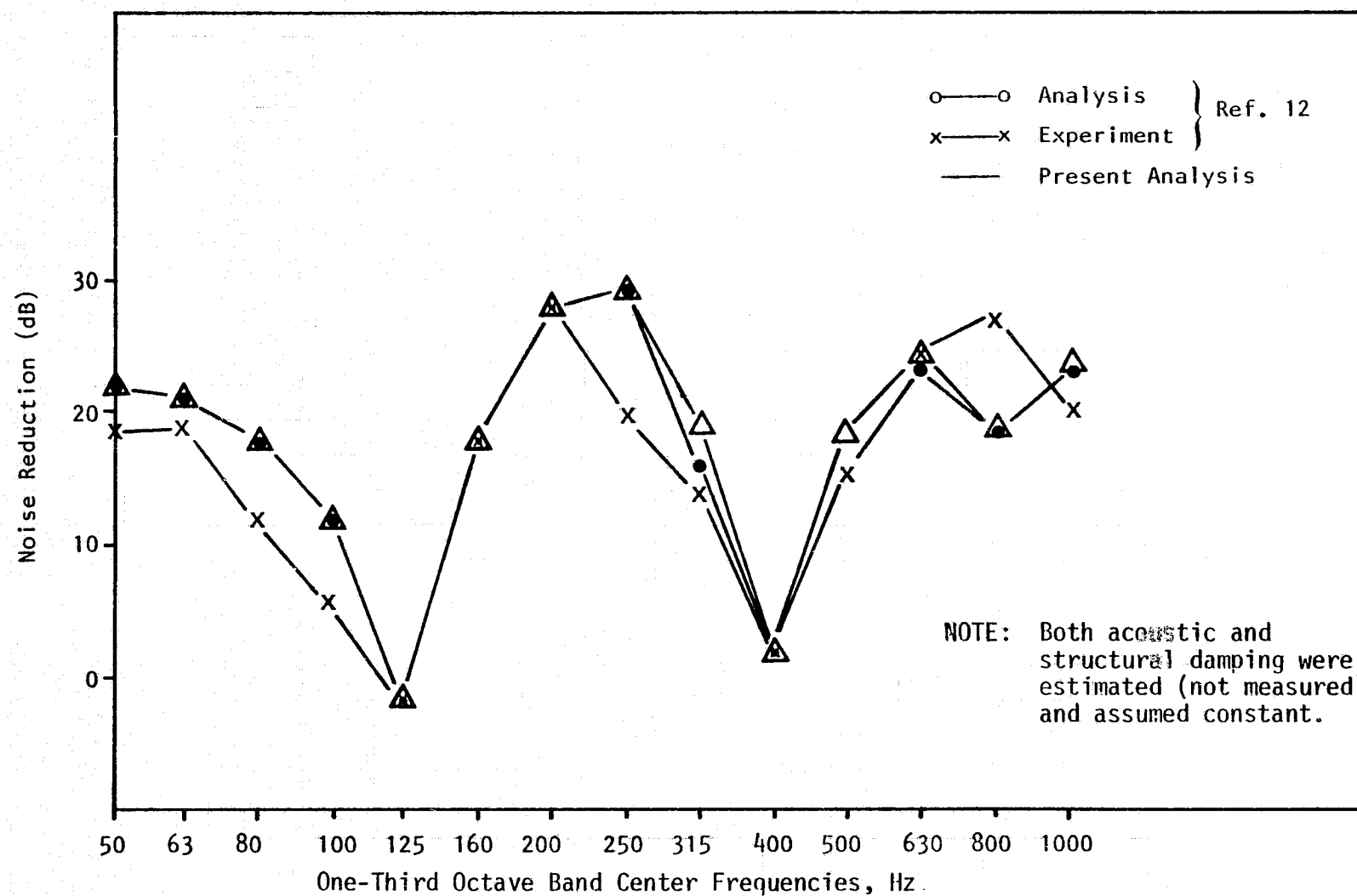


Figure 5. Modal Analysis Test Case Results, Band Average

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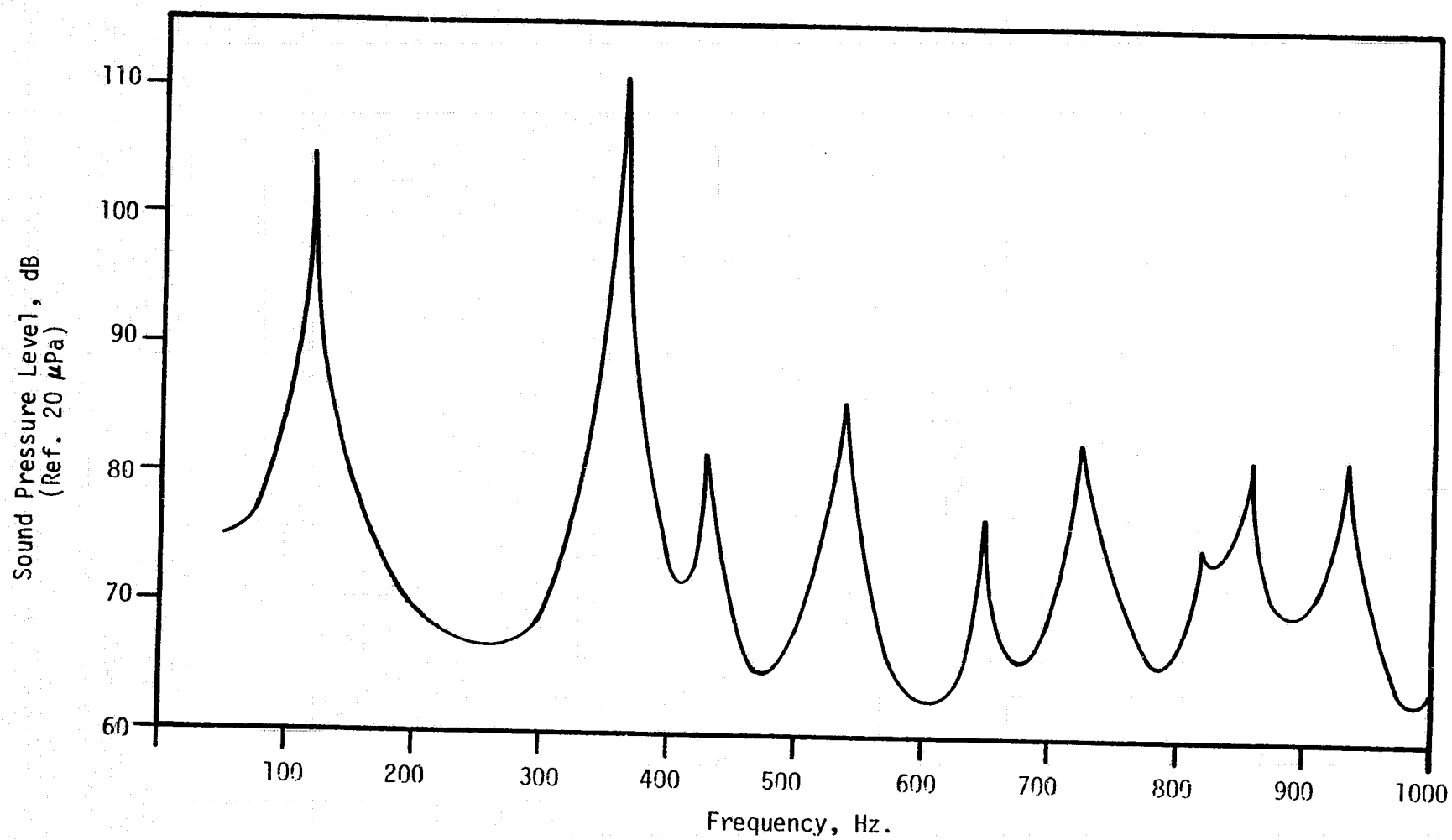
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Figure 6. Modal Analysis Test Case Results, Discrete Frequency

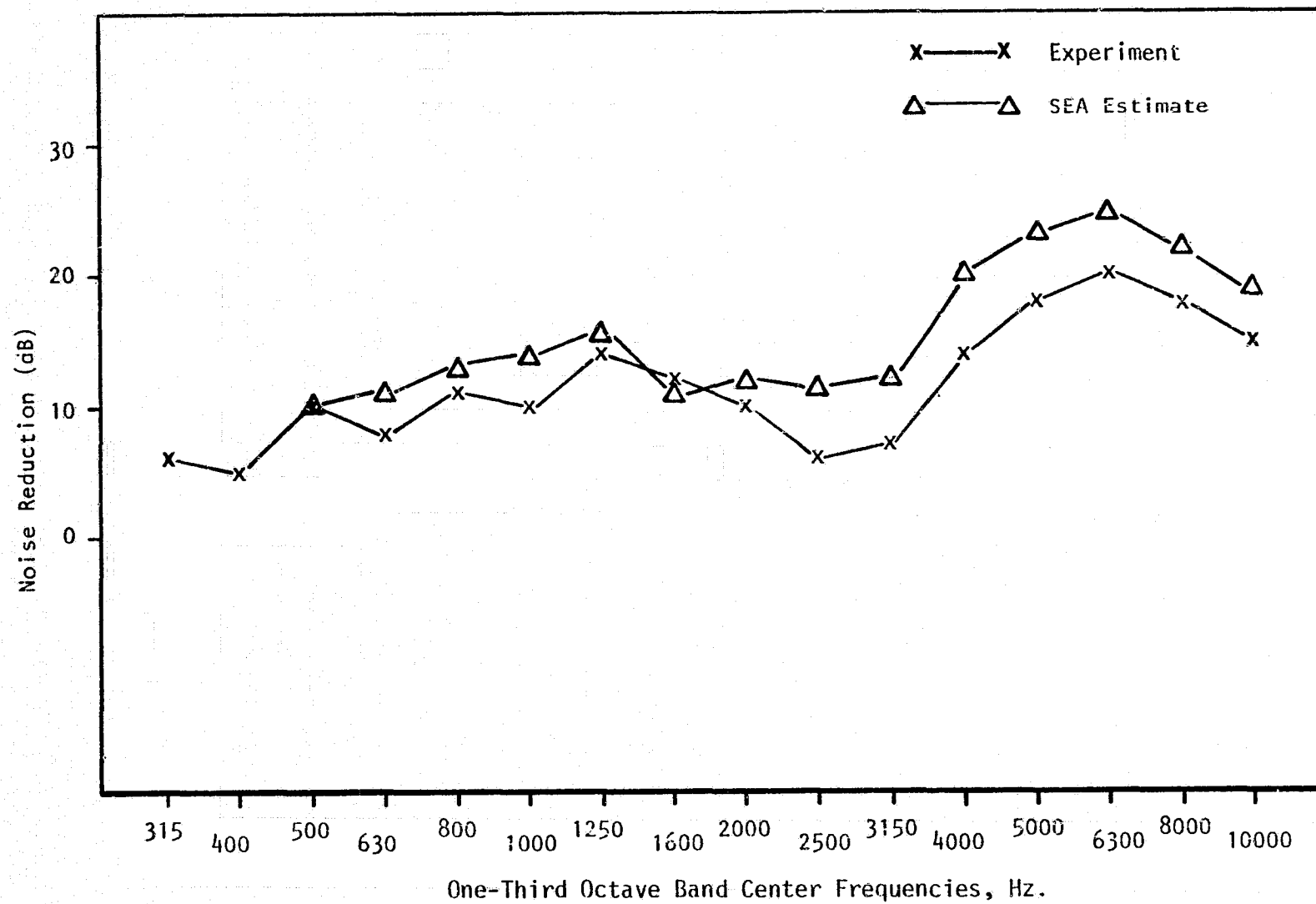


Figure 7. SEA Test Case Results

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While the multiple cavity capability may seem much more complex than the single cavity case, only one addition factor is added: the power flow through openings between cavities. Estimates of each opening's resistance to power flow are made in a very rough manner. Regardless of the opening's actual geometry, the conductance is estimated to be that of a baffled plane piston with the area of the opening. The estimate is "order of magnitude" at best. The larger the characteristic opening dimension to acoustic wavelength ratio (in the frequency band of interest), the better the estimate. If the openings are small enough to provide significant resistance to the flow of acoustic power, the validity of the multiple cavity interior noise estimates must be considered extremely suspect. The user can evaluate the significance of the resistance by doubling the area of the openings and recalculating the band-averaged pressure in each cavity. Large changes in the results will indicate significant resistance to power flow by the openings.

The intercavity conductance estimates must control only the pressure differential between the subvolumes, not the overall multiple cavity average level. Cavity absorption, the location and characteristics of transmission surfaces, and the external pressure field descriptions are factors that must dominate the overall multiple cavity results as they do the single cavity results. Unfortunately, an adequate multiple cavity test case could not be found in the literature for use in the evaluation of the intercavity pressure differential estimation capabilities of the model. The few experiments with multiple cavity measurements involved too many unknown variables for conclusive model verification. Given the frequency range of interest and the "opening significance" restriction above, however, the assumption that the relative opening areas between the subvolumes control the differential pressure can be considered strong in relation to other model assumptions.

Section 6

VIN USER'S MANUAL

This program will aid in the analysis of Vehicle Interior Noise (VIN) problems. Both modal and statistical energy analysis techniques are available to the user in a very generalized form. An overview of the steps required to use the program is given below. Each item will be fully described in turn.

VIN USER'S PROCEDURE

1. Review modal analysis method used in VIN.
2. Review statistical energy analysis method used in VIN
3. Graphically define geometry of the problem
4. Partition the volume into subvolumes and define openings
5. Idealize the structure for modeling
6. Number surface and volume elements and assign nodes
7. Update program library of elements
8. Estimate the structural damping and acoustic absorption
9. Define the external excitation on each surface and update program library of correlation fields
10. Prepare input data file
11. Prepare executive commands
12. Run program

6.1 Review Modal Analysis Method Used in VIN

The vehicle interior noise problem can be modeled by a set of coupled differential equations, one describing the structural response of the vehicle walls to excitation and the other representing the vehicle interior acoustics.⁽²⁾ The structure is modeled by standard linear Lagrangian relationships with differential pressure across the structural

walls as the driving force (point force input is also allowed). The acoustic model is based on Green's theorem in conjunction with small perturbation acoustical relationships. Using normal mode mathematical techniques, the set of equations are

Acoustics

$$\frac{\partial^2 P_n(t)}{\partial t^2} + \frac{A \rho C_o^2}{V} \sum_r \frac{C_{nr}}{M_r^a} \frac{\partial P_r(t)}{\partial t} + \omega_n^2 P_n(t) = \frac{-A}{V} \sum_m L_{nm} \frac{\partial^2 q_m(t)}{\partial t^2}$$

Structure

$$M_m \left(\frac{\partial^2 q_m(t)}{\partial t^2} + \frac{C}{M} \frac{\partial q_m(t)}{\partial t} + \omega_m^2 q_m(t) \right) = \rho c^2 A \sum_n \frac{P_n(t) L_{nm}}{M_n^a} + Q_m^e(t)$$

These equations can be solved in the time domain or fourier transformed and solved in the frequency domain for $P_n(t)$ or $P_n(\omega)$ respectively,

where

A = Surface area of vehicle structure

C = Structural viscous damping factor

c = Speed of sound in air

$$C_{nr} = \int_A \int 1/Z_a F_n^2(x_o) dA$$

$F_n(x_o)$ = Acoustic hard wall mode shape

$L_{nm} = \int_A \psi_m(x_o) F_n(x_o) dA$ - structural/acoustic modal coupling factor

M_r^a = Generalized acoustic mass of vehicle interior

M_m = Generalized mass of vehicle structure

$p^e(x_o, t)$ = External blocked pressure

$P_n(t)$ = n^{th} mode generalized pressure inside vehicle cavity at time, t

$q_m(t) = m^{\text{th}}$ mode generalized displacement of vehicle structure

$Q_m^e(t) = \int_A p^e(x_o, t) \psi_m(x_o) dA$ - generalized external force on structure

$V =$ Volume of vehicle cavity

$Z_a =$ Normal acoustic absorption coefficient for surface

$\rho =$ Density of air

$\psi_m(x_o) =$ Structural in vacuo mode shape

$\omega_m =$ Structural in vacuo natural frequency

With $P_n(\omega)$, the vehicle interior noise level can be calculated in any of the following forms:

Discrete frequency pressure squared at a point of specific interest

$$p^2(x_o, \omega) = \frac{\rho^2 c^4}{2} \sum_n \sum_{n'} \frac{F_n(x_o) F_{n'}(x_o)}{M_n^a M_{n'}^a} P_n(\omega) P_{n'}^*(\omega)$$

Band-limited pressure squared at a point of specific interest:

$$\langle p^2(x_o, \omega) \rangle_\omega = \frac{\rho^2 c^4}{2} \sum_n \sum_{n'} \frac{F_n(x_o) F_{n'}(x_o)}{M_n^a M_{n'}^a} \int_{\omega_1}^{\omega_2} P_n(\omega) P_{n'}^*(\omega) d\omega$$

Band-limited, space-averaged pressure squared:

$$\langle p^2(x_o, \omega) \rangle_{\omega, x_o} = \frac{\rho^2 c^4}{2} \sum_n \frac{1}{M_n^a} \int_{\omega_1}^{\omega_2} P_n(\omega) P_n^*(\omega) d\omega$$

Random external pressure fields are handled by taking the expected value of the above equations. Because of difficulties in obtaining the expected value of $P_n(\omega) P_{n'}^*(\omega)$, VIN will calculate only the band-averaged, space-averaged pressure when given a random external excitation.

Careful examination of these fundamental equations will show that the user must supply four types of information:

1. Vehicle geometry
2. Structural in vacuo response characteristics
3. Acoustic hard wall response characteristics and surface absorption
4. External excitation on vehicle structure

Often the geometry of the vehicle is so complex that the internal acoustic response characteristics are not known. VIN has a powerful acoustic component mode synthesis capability that calculates the acoustic response characteristics of a complex cavity shape from the known modal response of several simple shapes arranged to approximate that complex shape.

Calculation techniques based on two-dimensional fourier transforms were implemented in VIN to allow the use of finite element or experimental modal response data for the structure. Two simplifying assumptions, which significantly reduce the computation effort involved in this modal analysis technique, can usually be made without significant loss of accuracy. First, assume the acoustic natural frequencies are not significantly altered by the wall impedance ($C_{nr} = 0$ when $n \neq r$). Second, assume the internal acoustics do not significantly alter the structural natural frequencies,

$$\sum_n \frac{P_n(t) L_{nm}}{M_n^a} = 0$$

in the structural equation. VIN implements both of these assumptions to achieve significant reductions in computation time. An approximate technique is used to account for the retransmission of sound (loss of energy from inside to outside).

6.2 Review Statistical Energy Analysis Method Used in VIN

Statistical Energy Analysis (SEA) is a method of approaching vibrational problems using energy as the independent variable along with the time-honored assertion

$$\text{Energy In} = \text{Energy Out}$$

From this rather firm foundation, a series of assumptions, which form the essence of the approach, are made. These assumptions can be fairly rigorously stated as follows:⁽⁵⁾

1. The total vibrating system can be partitioned into SEA elements (with suitable boundary conditions) whose modes approximate the modes of the original vibrating system.
2. The energy in one frequency band of a system element is equally distributed among the modes of that element occurring in the frequency band.
3. The modes of the elements of a system contain all the vibratory energy of the system.
4. Only modes occurring within the same frequency band are coupled.
5. For two coupled elements, all the modes occurring in one of the elements in one frequency band are equally coupled to each mode occurring in the same frequency band in the other element.

Modal analysis, as described in section 6.1, is used in VIN to calculate the interior pressure in the lower frequency bands of interest. When there are sufficient acoustic modes occurring in a frequency band to make the SEA assumptions valid, VIN (or the user) can switch to the statistical energy method of calculating the response. The particular SEA formulation implemented in VIN is a modification of that found in reference 3. It allows the user to describe a system consisting of several interconnecting cavities, each with structural walls that can be exposed to external excitation. Power is allowed to flow through the structural walls to and from the external environment and through the openings connecting the cavities. Power is dissipated through structural damping and acoustic absorption. The power balance equation: Power In = Power Out

$$\{W\} = [C]\{p^2\}$$

$\{W\}$ is the input power matrix

$$W(k) = \sum_j W(k, j), \text{ where } j \text{ is a surface adjacent to volume } k$$

$[C]$ is the square coefficient matrix representing the output power from each subcavity

and

$$C(k, k) = C_a(k, k) + \sum_j C_j(k, k) + \sum_l C_l(k, k)$$

$$C(k, i) = \sum_l C_l(k, i)$$

$\{p^2\}$ is the band-limited mean square internal pressure in each cavity

$C_a(k, k)$ - power absorbed by the walls of each cavity

$C_j(k, k)$ - power reradiated through the transmitting walls of the cavity to the outside environment

$C(k, i)$ - power transferred to other subvolumes through openings connecting the cavities

$$W(k) = \sum_j W(k, j) \text{ where surface } j \text{ is adjacent to volume } k$$

$$= \sum_j \left[\left\langle \frac{S_{pbl}(\omega_c)}{\Delta\omega} \right\rangle \cdot \left(\frac{\rho A^4}{2\pi C_o} \cdot \sum_{b=(band-2)}^{band} n_b \cdot \left\langle \frac{J_b^2(\omega_c) J_b^{2rev}(\omega_c)}{M_b^2} \right\rangle_b \right. \right. \\ \cdot \int_{\omega_1}^{\omega_2} \frac{\omega^4}{|Y_b(\omega)|^2} d\omega + \frac{\rho A^4}{4\pi C_o} n_r \cdot \left\langle \frac{J_r^2(\omega_c) J_r^{2rev}(\omega_c)}{M_r^2} \right\rangle_r \\ \left. \cdot \frac{\pi \omega_c}{\eta} \right) \Bigg]_j$$

where

ρ = density of fluid in cavity

C_o = speed of sound in fluid

$\langle S_{pbl}(\omega_c) \rangle$ = space-averaged, band-limited mean square blocked pressure on the structure

A = area of surface

$S_{pbl}(\omega_c)$ = external blocked power spectral density of the surface pressure at frequency ω_c .

$$J^2(\omega) = \frac{1}{S_{pbl}(\omega_c) A^2} \int_A \int_{A'} S_{bl}(x_o | x'_o, \omega) \psi_m(x'_o) dA' dA$$

called the joint acceptance.

$S_{bl}(x_o | x'_o, \omega)$ = cross power spectral density of the external blocked surface pressure at frequency, ω .

$J^{2rev}(\omega)$ = joint acceptance of the internal reverberant field with the structure.

$\psi_m(x_o)$ = structural mode shape.

n_b = number of structural modes in band b.

n_r = number of structural modes in band r.

$\Delta\omega$ = frequency band width.

ω_c = center frequency of the band of interest.

η = structural damping loss factor.

M_b = average generalized mass of the structure in band b.

M_r = average generalized mass of the structure in band r, the band of interest.

$|Y_b(\omega)|^2$ = structural receptance squared, averaged over band b.

expanding on the output power matrix:

$$C(k, k) = C_a(k, k) + \sum_j C_j(k, k) + \sum_l C_l(k, k)$$

$$C(k, i) = \sum_l C_l(k, i)$$

$$C_a(k, k) = \frac{1}{2\rho C_o} \sum_j a_j A_j \quad \text{surface } j \text{ adjacent to volume } k$$

$$C_j(k, k) = \pi A^2 n_r \left\langle \frac{J_r^{2\text{rev}}(\omega_c)}{M_r} \right\rangle_r$$

With surface j adjacent to k

$$C_\ell(k, k) = \frac{A_\ell}{4\rho c} \frac{\theta_\ell}{(\theta_\ell^2 + \chi_\ell^2)}$$

$$C_\ell(k, i) = \frac{-A_\ell}{4\rho c} \frac{\theta_\ell}{(\theta_\ell^2 + \chi_\ell^2)}$$

where

a_j = normal surface absorption of surface j

A_j, A_ℓ = area of surface j and ℓ respectively

θ_ℓ, χ_ℓ = opening correlation factors

Careful examination of the SEA equations will show that the user must supply four types of information:

1. Vehicle geometry
2. Structural high frequency response characteristics
3. Surface absorption of acoustic energy
4. External excitation description

6.3 Graphically Define Geometry of the Problem

Prepare a clear and uncluttered isometric or three view plan drawing of the vehicle. The scaled drawing should show the outline of the vehicle's cavities and not the structural details of the vehicle's walls. A rectangular, global coordinate system should be established on the drawing.

6.4 Partition the Volume Into Subvolumes and Define Openings

Often the internal geometry of a problem is so complex that the acoustic modal response characteristics are not known. With VIN's acoustic component mode synthesis

capability, the user can calculate the modal response characteristics of the complex cavity. The interior of the vehicle, or the cavity, must be partitioned or further idealized as several simple shapes with known hard wall acoustic modes connected together to approximate the more complex shape. The connection between the subcavities are termed openings. The mode shapes of each opening must also be known. The response characteristics of each subvolume and opening is held in the program's library of elements, which is fully described later.

VIN can calculate the space-averaged pressure squared over each subvolume. This provides valuable information on the spacial distribution of the acoustic pressure in the vehicle.

When the acoustic modal density is greater than 6 or 7 modes per one-third octave, the response characteristics can be considered reverberant and therefore independent of cavity shape. When this is the case, statistical energy analysis can be used. The subvolumes are retained for the statistical energy analysis and are termed acoustic SEA elements with reverberant response characteristics. In this way, the spatial distribution of the acoustic pressure can also be estimated in the high frequency regime since the average pressure in each subvolume is calculated.

6.5 Idealize the Structure for Modeling

The primary concern in the development of the drawing has been the representation of the vehicle's interior acoustic geometry. In this step, the structural elements are identified and related to the subvolumes of the problem defined in section 6.4. The idealized structure will consist of transmission surfaces and absorption surfaces. These surfaces must lie on or within the bounds of the subvolumes that idealize the acoustic geometry. It is preferable for the idealized structures to lie on the bounds of the subvolume, but some approximation is allowed. Transmission surfaces are surfaces that may vibrate and transmit acoustic energy into the subvolumes. Absorption surfaces are surfaces that may absorb acoustic energy but are assumed to be rigid. The drawing should be modified so that it consists only of surface and subvolume elements that are in the program's element library.

The motion of each portion of the vehicle's structure is dependent, to some degree, on the motion of all other parts of the vehicle. In essence, the vehicle has only one

transmission surface. In many cases, however, sections of the vehicle structure are well insulated from each other by rigid or relatively massive boundaries, and the structures respond somewhat independently from each other. Each structural wall of the vehicle whose motion can be independently described is termed a "master surface." The user is required to define the structural response characteristics of each master surface. The details of how this is accomplished is described in later sections.

Any master surface that extends over two or more subvolumes must be partitioned into subsurfaces, one for each subvolume that is bounded by that particular master surface. This is required because of the calculation techniques used in VIN. The response characteristics of each subsurface is calculated by VIN from the master surface data supplied by the user. Each subsurface can be assigned different acoustic absorption characteristics.

The master surface declaration can be used in conjunction with the definition of the master surface response characteristics to build a model of the structure that is valid over a larger range of frequencies. Consider, for example, a frame-stiffened structure. At low frequencies, the structure has modal characteristics that span its whole length. At higher frequencies, however, the panels bounded by the frames may vibrate somewhat independently. To represent this behavior, the user may define one master surface that describes the low frequency modes and several other surfaces to represent the higher frequency behavior. All that is required of the user to implement this double description of a structure is to simply doubly describe the structure and make sure the response characteristics assigned to each do not overlap in the frequency domain.

An absorption surface should be defined so that no portion of the surface bounds more than one subvolume. A subvolume may have as many absorption surfaces as the geometry requires. Since the acoustic independence of each absorption surface must be constant, multiple absorption surfaces can be used to model acoustic impedance variations over a wall. At this point, the isometric drawing should consist only of surface and volume elements that are resident in the program's element library.

6.6 Number Surface and Volume Elements and Assign Nodes

With the isometric drawing now consisting only of surface and subvolume elements with known response characteristics, preparations must be made for communication of this

geometry to the program. First, starting at one end of the vehicle and working to the other, number each subvolume. Second, number all the openings. Third, starting with 1, number all the master transmission surfaces in the same orderly manner. Third, continue the surface tally by numbering the transmission subsurfaces. Fourth, continue the surface tally by numbering the absorption surfaces. The total number of surfaces counted are

$$NS = NMS + NSS + NAS$$

NS = number of surfaces

NMS = number of master transmission surfaces

NSS = number of transmission subsurfaces

NAS = number of absorption surfaces

The geometry of each of the surface, volume, and opening elements is communicated to the program by a method similar to that used in large finite element programs. Each element (master transmission surface, transmission subsurface, absorption surface, subvolume and opening) is identified by type. A certain number of "nodes," or position points, are associated with each element type. Documentation for the program libraries defines where the nodes should be located on each element type. The nodes associated with each element type should be clearly marked and numbered on the isometric drawing. A node can and should be used, if possible, in the definition of more than one element. The nodes associated with each element type define the orientation of the element's geometry with respect to its own local rectangular coordinate system and the global coordinate system of the problem as a whole. The nodes also provide the limits for surface integration purposes. A minimum of three nodes are required to define an element type. The first node fixes the location of the origin of the element's coordinate system in the global coordinate space. The second and third nodes also provide limits for surface integration purposes in many of the element types. Any additional nodes provide the reference points required to fully define the element geometry. The maximum number of nodes needed is solely a function of element type.

The description of the element geometry is completed by the analytical information held in SGEOM, which calculates

$$Z = f(x, y)$$

and

$$G(x, y) = \sqrt{1 + \left(\frac{\partial z}{\partial x}\right)^2 + \left(\frac{\partial z}{\partial y}\right)^2}$$

where

$Z = f(x, y)$ is equation of the surface

$\frac{\partial z}{\partial x}$ is the partial derivative of z with respect to x

$\frac{\partial z}{\partial y}$ is the partial derivative of z with respect to y

This information is required for accurate surface integration.

Elements are differentiated by response characteristics and not geometry. For example, a rectangular panel with ribs may be in the library as element 5, while a simple rectangular panel without ribs is element 2.

6.7 Update Program Library of Elements

The geometry and modal response characteristics of all the elements used in the drawing completed according to the directions of section 6.6 must be known. The program library contains some commonly used structural and acoustic elements. The library was not intended, however, to be static. Rather, the library provides a simple and structured means for the user to add geometry and response information for the user's particular problems as they arise. If library elements, from past problems, fit the present problem, then they may be used. This source code held library has the following organization:

Program Library of Elements

- A. Program library of modal elements
 - I. Volume elements
 - II. Opening elements
 - III. Analytic volume/opening coupling, L_{nm}
 - IV. Structural elements
- B. Program library of SEA elements

In addition to the program libraries held in the source code, VIN provides an orderly method of maintaining data files of structural and acoustic response characteristics and program-calculated parameters associated with specific structures and volumes. The data file capability significantly reduces the computational effort associated with design studies where the effect of various parameter changes are investigated. Essentially all cogent information is placed in mass storage so that it can be retrieved in total or in part for use in a similar problem. (That is, a slightly changed structure, increased damping, or adding a wall in the acoustic space constitutes a new problem but does not invalidate many of the parameters calculated previously.)

Data File

- A. System specific parameters
- B. Structural surface specific parameters

6.7.1 Program Library of Modal Elements

Surface integrations involving structural and acoustic mode shapes are the heart of the modal analysis equations. The program library of modal elements provides for the calculation of these surface integrals. The modal information can be held in the library in several different forms. All mode shape definitions are given in the particular element's coordinate system. Recall that the complex cavity mode shapes are represented by a series of coefficients multiplied times the hardwall acoustic mode shape of the cavity's subvolumes:

$$F_{n'}(x_o) = \sum_n P_n(n',v) F_n^v(x_o) / M_n^a$$

where

$F_{n'}(x_o)$ = mode shape of the n' mode of the multiple cavity system

$P_n(n',v)$ = influence coefficient of n' cavity mode for subvolume v

$F_n^v(x_o)$ = hardwall acoustic mode shape of subvolume v

The volume or acoustic modal element descriptions provides the hardwall acoustic mode shapes, $F_n^v(x_o)$.

The opening modal elements are needed for acoustic component mode synthesis. Acoustic component mode synthesis requires the calculation of coupling factors, L_{nm} ,

between the subvolumes of the cavity and the openings that connect the subvolumes. Recall that

$$L_{nm} = 1/A \iint_A \psi_m(x_o) F_n(x_o) dA$$

where

$\psi_m(x_o)$ = opening mode shape

$F_n(x_o)$ = hardwall subvolume acoustic mode shape

A = area of opening

Provision is made in the component mode synthesis portion of the program code for analytic calculation of the opening/subvolume L_{nm} . If analytic calculation is not possible, then the integration is carried out by gaussian quadrature.

Structural mode shapes can be in analytical or double sine series form. The double sine series can represent structural mode shapes from extensive analytical techniques, finite element analysis, and/or experiment.

Examine the documentation for the program library of modal elements in appendix A. The volume elements now held in the program code are

1. Rectangular parallopiped
2. Circular cylinder with closed ends
3. Concentric circular cylinder with closed ends

The opening elements now held in the program code are

1. Rectangle
2. Circle
3. Concentric circular annulus

The volume/opening analytic coupling L_{nm} are

1. Rectangle/parallopiped
2. Circle/circular cylinder
3. Concentric circular annulus/circular cylinder
4. Concentric circular annulus/concentric circular cylinder annulus

The structural elements held in the program code are

1. Rectangular surface shape with Fourier series mode descriptions
2. Thin, orthotropic, rectangular panel with simply supported edges
3. Circular surface shape with Fourier series mode descriptions
4. Thin, homogeneous, circular panel with fixed edges
5. Frame-stiffened, orthotropic whole-shell segment with shear end conditions at cylinder ends
6. Frame-stiffened, orthotropic shell segment with shear end conditions at all boundaries.
7. BBN finite element mode shape description method.
8. Thin, orthotropic rectangular panel with clamped edges.

Additional element types can be added to the library as required. The following instructions describe how an update is made.

The documentation for the new elements should be fully prepared before any additions to the source code are made. Acoustic modal element documentation should follow the pattern.

- a. Element number assignment and description
- b. Drawing of the element, including locations of the element nodes
- c. Natural frequency equations
- d. Mode shape equations
- e. Summary program variables associated with volume elements

a. Element number assignment

The element is accessed via its unique element number. The description is for comments in the program code and for titles in the documentation.

b. Drawing of the element, including locations of the element nodes

The element geometry is depicted on a rectangular coordinate system in a manner most conducive to defining the shape with the least number of nodes. The nodes are located such that

- Node 1 - at the origin of the coordinate axis
- Node 2 - on the positive x-axis
- Node 3 - on the positive y-axis
- Node 4 - on the positive z-axis

Additional nodes may be assigned as required to supply the needed dimensions in the natural frequency and mode shape equations.

c. Natural frequency equations

Using basic acoustic constants and the dimensions supplied by part two, provide an equation for the calculation of the hardwall acoustic natural frequency as a function of mode number (modal index).

d. Mode shape equations

Using the dimensions supplied in part two, provide an equation for the calculation of the hardwall acoustic mode shape as a function of position and mode number. The mode shapes must be normalized such that

$$M_n^a = 1/V \iiint F_n^2(x_o) dV = 1.0$$

e. Summary of program variables associated with volume element descriptions

The program variables to be used in the volume element descriptions are summarized in part e.

Opening modal element and analytic L_{nm} documentation should follow the pattern:

- a. Element number assignment and description
- b. Drawing of the element, including location of the element nodes

c. Mode shape equations

d. Summary of program variables associated with opening element descriptions

a. Element number assignment and description

The opening element is accessed via its unique opening element number. The description is used in organizational comments in the program code and for titles in the documentation.

b. Drawing of the element, including location of the element nodes

The opening element geometry is depicted on a rectangular coordinate system in a manner conducive to defining the shape with the least number of nodes. The nodes are located such that

Node 1 - at the origin of the coordinate axis

Node 2 - on the positive x-axis at the furthest extent of the element in the x-direction

Node 3 - on the positive y-axis at the furthest extent of the element in the y-direction

Additional nodes may be assigned as required to supply the needed dimensions in the mode shape equations.

c. Mode shape equations

Using the dimensions supplied in part II, provide an equation for the calculation of the opening mode shapes. The opening types have certain "allowed frequency" constant that also affect the mode shape. Equations for calculating these values as a function of modal index numbers must also be provided.

d. Summary of program variables associated with opening element description

The program variables to be used in the opening element descriptions are summarized.

Structural modal element documentation should follow the pattern:

a. Element number assignment and description

b. Drawing of the element, including location of the element nodes

- c. Surface equations
- d. Natural frequency equations and structural constants
- e. Mode shape equations
- f. Summary of program variables associated with structural element

a. Element number assignment and description

The element is accessed via its unique element number. The description is for organizational comments in the program code and for titles in the documentation.

b. Drawing of the element, including location of the element nodes

The element geometry is depicted on a rectangular coordinate system in a manner conducive to defining the shape with the least number of nodes. The structural element may be three-dimensional as long as it is single valued in the z-direction (component coordinate system). The nodes are located such that

Node 1 - at origin of the coordinate axis

Node 2 - on the positive x-axis at the furthest extent of the element's projection in the x-direction

Node 3 - on the positive y-axis at the furthest extent of the element's projection in the y-direction

Additional nodes may be assigned as required to supply the needed dimensions in the natural frequency and mode shape equations.

c. Surface equations

An equation of the surface is established as a function of the component x and y positions: $z = f(x,y)$. As described in section 6.6, a correction factor for the surface shape must also be supplied for surface integration:

$$G(x,y) = \sqrt{1 + \left(\frac{\partial z}{\partial x}\right)^2 + \left(\frac{\partial z}{\partial y}\right)^2}$$

Note that if $z = \text{constant}$, $G(x,y) = 1.0$. The jacobian of the coordinate system of integration must also be provided.

d. Natural frequency equations and structural constants

Supply the structural constants and the equation needed to calculate the structural element's natural frequencies. Alternatively, the natural frequencies can be supplied as data by the user. If this is done, the mode shapes must also be given by data, in which case the structural element description held in the program code reduces to a simple description of the surface geometry for integration purposes.

e. Mode shape equations

Using the dimensions supplied in part II and the constants supplied in part IV, provide an equation for the calculation of the structural mode shapes. Alternatively, the mode shapes can be given by data (double sine series) as discussed in part IV above.

f. Summary of program variables associated with structural element description

The program variables to be used in the structural element descriptions are summarized.

The mode shape data can be supplied directly in double sine series form or as raw data in the NASTRAN output format. The program converts the Nastran output formatted data to double sine series form. All mode shapes will be normalized such that

$$M_m = 1/A \iint_S \psi_m^2(x_o) ds = 1.0$$

Once the documentation is completed, the information must be added to the program source code. The fully commented code (appendix D) in combination with the documentation for the program library of modal elements (appendix A) clearly demonstrates how the volume, opening, and structural elements are to be added to the code.

6.7.2 Update Program Library of SEA Element Types

The geometry of the problem, as defined by the isometric drawing completed in section 6.6, remains valid throughout all program computations regardless of the computation method--modal analysis or SEA. The equations for the structural mode shapes and natural frequencies given for the master surfaces in section 6.7.1 may not, however, be

suitable to reflect the statistical emphasis needed in the higher frequencies for good SEA estimates. Consequently, VIN holds a library of structural SEA descriptions that may be assigned to any of the master surfaces. Appendix B documents the SEA descriptions presently in the library and the parameters associated with them. The acoustic SEA elements are assumed to exhibit the well-known reverberant field characteristics and hence are shape independent.

Examine the documentation for the program library of SEA descriptions in appendix B. The SEA descriptions now held in the program code are

1. Equivalent rectangular panel with end conditions ranging from simply supported to clamped.
2. Equivalent orthotropic whole shell with shear diaphragm end conditions.
3. Direct data: RJA, RJARV, MD.

Additional SEA descriptions can be added to the library as required. The following defines the procedure for making an update.

The documentation for the new elements should be fully prepared before any additions to the source code are made. SEA documentation should follow the pattern:

- a. SEA description number assignment
 - b. Modal density equations
 - c. Joint acceptance equations
 - d. Summary of program variables associated with SEA element description.
- a. SEA description number assignment
- The SEA response description is accessed via its unique SEA response description number.
- b. Modal density equations

Supply the equations needed to calculate the modal density of the element as a function of frequency. Frequency dependent constants can be defined and held in the "SEA constants" array, WMH (NSEAC, NTOB), where NSEAC is the number of SEA

constants and NTOB is the number of frequency bands. These and/or additional constants are also used in part 4.

c. Typical joint acceptance definition

The joint acceptance may be calculated either directly by user-supplied, semi-empirical equations or by the program's analytical integration of equivalent mode shape descriptions. Frequency dependent parameters required by the selected method may be held in the array WMH as discussed previously. Either or both methods may be used in a single problem.

d. Summary of program variables associated with SEA descriptions

Once the documentation is complete, the information must be added to the program source code. The fully commented code (appendix D) in combination with the documentation for the program library of SEA elements (appendix B) clearly demonstrates how the SEA elements are to be added to the code.

6.7.3 Organization and Use of Data File

All cogent information for any problem solved by VIN can be stored in a data file so that the information may be retrieved in total or in part for use in a similar problem. The data file holds two types of information: system specific and structural surface specific parameters. The system specific parameters are stored in files L1-L6. These described the geometry, acoustics, and acoustic dependent parameters of the problem. The structural surface specific parameters are stored in files L7-L10. These describe the dynamics of structural elements, including generalized force as specified for that surface. Mass storage files L16-L18 are sometimes required for short-term storage of intermediate calculations and are not a part of the permanent data file.

Each problem stored receives a unique problem number. Each structural surface element stored receives a unique "stored" structural element number. File L0 contains an index of the stored data. The index is printed whenever prestored data is used. The output of file L0 provides the following information:

Data SetContents

1. NTAPE - Reference number for control card addressing
 - NFV - Problems
 - NFS - Master surfaces
 - NPFCT - Pressure field constants
 - NTOBT - Frequency bands
 - NVT - Volumes in multiple cavity system
 - NST - Surfaces in multiple surface system
 - MXVT - Volume element nodes
 - MXST - Surface element nodes
 - NAMT - Acoustic modes
 - NSMT - Structural modes
 - MXT - Fourier series m-direction limit
 - NXT - Fourier series n-direction limit
 - NAMMCT - Important acoustic modes
 - NSEACT - SEA constants
 - NPA - Actual number of problems now on data set
 - NSA - Actual number of surfaces now on data set

Data SetContents

Problem

2. NN - Nodes
 - NS - Surfaces
 - NMS - Master surfaces
 - MNSS - Subsurfaces
 - NAS - Absorption surfaces
 - MXS - Surface nodes
 - NSMX - Structural modes
 - NSC - Structural constants (modal analysis)
 - NV - Volumes
 - NXV - Volume nodes
 - NAM - Volume modes
 - NTOB - Frequency bands
 - MFE - Surfaces with finite element descriptions

MX - Fourier series terms in x-direction
 NX - Fourier series terms in y-direction
 NSEAC - SEA constants
 NPFC - Pressure field constants
 NWS - Discrete frequency steps over frequency range
 NOO - Openings
 LBAND - Lowest band of interest: Modal analysis
 MBAND - Transition band: End modal analysis; begin SEA analysis
 IHBAND - Highest band of interest
 RO - Density of fluid in volume
 CO - Speed of sound of fluid in volume
 VOL - Volume of multiple cavity system
 PREF - Reference pressure
 ZERO - Value considered zero
 EPS - Fraction of peak modal contribution considered negligible
 BW - Bandwidth

A set of these parameters is given for each problem stored on the data tape.

<u>Data Set</u>	<u>Contents</u>
	Structural Element
3	ISTYP - Surface type NM - Modes of structure NSC - Structural modal constants IPF - Pressure field type LBAND - Low band MBAND - Transition band IHBAND - High band NSEAC - SEA constants ISEAO - SEA structural type

A set of this data is held for each structural type on the data tape.

Random access storage parameters:

MNR = 1 + 10 + 20 (maximum number of records)
 MRS = 20 (maximum record size)

IR = 1 for tape parameters
 = 1 + NPROB for problem parameters
 = 1 + 10 + ISUR for structural parameters

Note that this first file is sized with constants so that it may be read without prior knowledge of the value of the parameters on the file.

File L1: Problem Geometry

Data Set (NDS)

- 1 VNODC(MXV,3,NV) - Volume node locations (in subvolume coordinate system)
 - VTM(3,3,NV) - Transformation matrix for global-to-volume system
 - VORG(3,NV) - Origin offset: Volume-to-global coordinate system
 - IVTYP(NV) - Volume type
- ONODC(MXS,3,NOO) - Opening node locations
 - OTM(3,3,NOO) - Transformation matrix for opening to global system
 - OORG(3,NOO) - Origin offset: Opening to global coordinate system
 - IOTYP(NOO) - Opening type
- SNODC(MXS,3,NS) - Surface node locations (in surface coordinate system)
 - STM(3,3,NS) - Transformation matrix for global-to-volume system
 - SORG(3,NS) - Origin offset: Surface-to-global coordinate system
 - ISTYP(NS) - Surface type: Modal analysis
 - V(NV) - Volume of subvolumes
- AREAO(NOO) - Area of openings
- AREA(NS) - Area of surfaces
- IGEMOV(2,NOO) - Opening/subvolume relationships
 - ISV(NS) - Surface/subvolume relationships
- MASSUR(NMS,MNSS) - Master surface/subsurface relationships
- NSDAT(NS) - Data tape surface identification
- CENTF(NTOB) - Center frequencies of frequency range of interest

IFE(NMS) - Surface with finite element description
 identification
 ISEAO(NMS) - Surface type: SEA
 GNODE(NN,3) - Global node points
 IOCM(MXS,NOO) - Opening nodes
 ISURCM(MXS,NS) - Surface nodes
 IVOLCM(MXV,NV) - Volume nodes
 BNDWN(NTOBT,2) - Acoustic band of importance

Random access storage parameters:

MNR = NFV; maximum records in file
 MRS = Total size of arrays above; maximum record size
 IR = NPROB; mass storage record access number

File L2 - Subvolume Natural Frequencies and Acoustic Mode Shape
 Integration Over Each Surface

Data Set (NDS)

- 1 WN(4,NAM,NV) - Natural frequency and mode shape index of
 subvolumes
- 2 CN(NAM,NS) - Integral of whole cavity acoustic mode shape over
 each surface
- 3 ZNDATA(NTOB,NS) - Surface acoustic absorption

Random access storage parameters:

MNR = NFV*3
 MRS = AMAX(NST*NAMT, 4*NAMT*NVT)
 IR = (NDS-1)*NFV+NPROB

File L3: Acoustic Modal Response

Data Set (NDS)

- 1 WNMC(NAM) - Multiple cavity system's acoustic natural
 frequencies
- 2 VMNPA(NAM) - Generalized mass of each acoustic mode
- 3 ZANN(NAM) - Cavity acoustic damping

Random access parameters:

$$\text{MNR} = \text{NFV} * 3$$

$$\text{MRS} = \text{NAMT}$$

$$\text{IR} = \text{NPROB} + (\text{NDS} - 1) * \text{NFV}$$

File L4: Portion of Cavity Generalized Mass in Each Subvolume

Data Set (NDS)

- 1 **RMN(NAMT,NVT) - Portion of cavity generalized mass in each subvolume**

Random access storage parameter:

$$\text{MNR} = \text{NFV}$$

$$\text{MRS} = \text{NVT} * \text{NAMT}$$

$$\text{IR} = (\text{NPROB})$$

File L5: Acoustic Component Mode Synthesis Constants of Constraint

Data Set (NDS)

- 1 **PNMC(NAMMC) - Constants of constraint**

Random access storage parameters:

$$\text{MNR} = \text{NAMT} * \text{NVT} * \text{NFV}$$

$$\text{NRS} = \text{NAMMCT}$$

$$\text{IR} = (\text{NPROB} - 1) * \text{NAMT} * \text{NVT} + (\text{NVOL} - 1) * \text{NAMT} + \text{NWN}$$

File L6: Modal Selection for Constants of Constraint

Data Set (NDS)

- 1 **INDPN(NAM) - Indicates which subvolume acoustic modes are important in the calculation of the whole cavity modes**

Random access storage parameters:

$$\text{MNR} = \text{NVT} * \text{NFV}$$

$$\text{MRS} = \text{NAMT}$$

$$\text{IR} = (\text{NPROB} - 1) * \text{NVT} + \text{NVOL}$$

File L7: Structural/Acoustic Coupling Coefficient

Data Set (NDS)

1 VLNM(NAMT) - Structural/acoustic coupling coefficient

Random access storage parameters:

$$\text{MNR} = \text{NSMT} * \text{NST}$$

$$\text{MRS} = \text{NAMT}$$

$$\text{IR} = (\text{ISUR}-1) * \text{NSMT} + \text{MWM} + \text{NSMT} * \text{NST} * (\text{NPROBN}-1)$$

The structure specific parameters held in files L8 through L15 are briefly described in the following data file summary.

File L8: Miscellaneous Structural Constants

Data Set (NDS)

1 NM,ISTYP,AREA - Number of modes, structure type, structure area

2 SC(NSC) - Structural constants for modal analysis

3 ZMDATA(NTOB) - Structural damping in each band of interest

4 SPL(NTOB) - Exterior sound pressure level on structure for each band of interest

Random access storage parameters:

$$\text{MNR} = 4 * \text{NFS}$$

$$\text{MRS} = \text{NTOBT}$$

$$\text{IR} = (\text{NDS}-1) * \text{NFS} + \text{NSDAT}(\text{ISUR})$$

File L9: Structural Modal Data

Data Set (NDS)

1 WM(3,NSMT) - Structural modes and modal indexes

2 ZM(NSMT) - Structural modal damping (C/C_c)

Random access storage parameters:

$$\text{MNR} = \text{NFS} * 2$$

$$\text{MRS} = 4 * \text{NSMT}$$

File 10: Generalized Force: Modal Analysis

Data Set (NDS)

- 1 RJA(NTOBT) - Joint acceptance or generalized force of each structural mode for the given external pressure field

Random access storage parameters:

MNR = NFS*NSMT

MRS = NTOBT

IR = (NSDAT(ISUR)-1)*NSMT+MWM

File L11: (Blank and not assigned)

File L12: Structure Modal Description

Data Set (NDS)

- 1 BPQ(MXT,NXT,NSMT) - Coefficients to double Fourier series description of mode shape

Random access storage parameters:

MNR = NFS

MRS = MXT*NXT*NSMT

IR = NSDAT(ISUR)

File L13: Structure SEA Response Description

Data Set (NDS)

- 1 WMH(NSEAC,NTOB) - Structural SEA parameters for each frequency band of interest

Random access storage parameters:

MNR = NNFS

MRS = NSEACT*NTOBT

IR = NSDAT(ISUR)

File L14: Structure SEA Joint Acceptance and Modal Density

Data Set (NDS)

- 1 RJA(NTOB) - Joint acceptance of modes in band (given external field)
- 2 RJARV(NTOB) - Joint acceptance of modes in band (reverberant pressure field)
- 3 MD(NTOB) - Modal density

Random access storage parameters:

$$\text{MNR} = 3 * \text{NFS}$$

$$\text{MRS} = \text{NTOBT} * 2$$

$$\text{IR} = (\text{NDS} - 1) * \text{NFS} + \text{NSDAT}(\text{ISUR})$$

File L15: Bandwidth of Importance

Data Set

- 1 BNDWM(NTOB,2)

Mass storage parameters:

$$\text{MNR} = \text{NFS}$$

$$\text{MRS} = \text{NTOB} * 2$$

$$\text{IR} = \text{NSTOR}(\text{IS})$$

The following three files are used for short-term storage of intermediate program calculated parameters. The files are not part of the permanent data set.

L16: EIMTX

- 1 EIMTX(NOO,NOM) - Constraint constants at the openings

$$\text{MNR} = \text{NAM}$$

$$\text{MRS} = \text{NOO} * \text{NOM}$$

$$\text{IR} = \text{NWN}$$

L17: VLNM

- 1 VLNM(NAM,NMO) - LNM for openings and volumes in acoustic component mode synthesis

MNR = NOO*2
MRS = NAM*NMO

where

IF(IGEMOV(1,INO).EQ.NVOL)INV = 1
IF(IGEMOV(2,INO).EQ.NVOL)INV = 2
IR = (INV-1)*NOO+INO

File L18

Data Set (NDS)

1 NFES,NSM
((I,D1(I),D2(I),D2(I)),I=1,NFES),
((I,VM(I)),I=1,NFES),
((I,WM(I),(((SN(K,J,I),I=1,NSM),K=1,NFEN),J=1,3)

where

NFES - FE nodes in the data set
NSM - FE modes in the data set
D1 - x-coordinate in FE system of F.E. node
D2 - y-coordinate
D3 - z-coordinate
VM - Elemental mass at each node
WM - Natural frequencies
SN - Array of mode shapes, three translational degrees
of freedom

Mass storage file parameters:

MRS = 6*MFE+2*NSMT+NSMT*3*MFE
MNR = NFES
IR = IFE(ISUR)

6.8 Estimate the Structural Damping and Acoustic Absorption

The structural damping and normal acoustic impedance must be estimated for the entire frequency range of interest for each master surface of the structure. The prediction accuracy of the program is usually affected more by estimates of these parameters than by any other single aspect of the modeling exercise. Because of the uncertainties usually associated with these factors, the user is advised to arrive at the

answer to important problems based on a sensitivity analysis with damping and surface absorption as the variables. Such a sensitivity analysis would be less costly than it seems since VIN can save the results of the program's most time-consuming calculations for reuse in repeated runs of the same general problem.

6.9 Define External Acoustic Fields

The external acoustic field over each master surface must be specified. The program library of external pressure fields contains normalized descriptions of the most commonly encountered pressure fields. Each pressure field type is assigned a unique pressure field reference number. The program library of external pressure fields may be updated. The documentation follows the pattern:

- a. Pressure field number assignment and description
- b. Surface pressure field correlation equations
 1. Random: frequency domain
 2. Deterministic: frequency domain
- c. Generalized force calculations

a. Pressure field number assignment and description

Each pressure field description is accessed via its unique element number. The description is for comments in the program code and for titles in the documentation.

b. Surface pressure field correlation equations

A pressure field is described in either random-frequency domain or deterministic-frequency domain terms. Each description is normalized to a reference pressure at the centroid of the surface on which the field is imposed. The description should be in the form of an equation. All constants that make the description more versatile are identified and allowed to be user-variable inputs to the program. (See documentation for program library of external pressure fields.)

c. Generalized force calculations

Since the equations are formulated to calculate the space-averaged pressure squared, the generalized force is required in the form of a joint acceptance:

$$J_{mm}^2(\omega) = \frac{1}{A^2} \int_s \int_{s'} \frac{S_{pbl}(x_o | x'_o, \omega)}{S_{pbl}(\omega)} \psi_m(x_o) \psi_m(x'_o) ds ds'$$

where

$S_{pbl}(\omega)$ = exterior blocked pressure power spectral density at a reference point

$S_{pbl}(\omega)$ = exterior blocked pressure cross-power spectral density

A = surface area of structure

While this form is generally used for random external pressure field descriptions, it can also be used with deterministic data.

$$J_{mm}^2(\omega) = \frac{1}{A^2} \int_s \int_{s'} \frac{p(x_o, \omega) p^*(x'_o, \omega)}{|p(x_{ref}, \omega)|^2} \psi_m(x_o) \psi_m(x'_o) ds ds'$$

where

$p(x_o, \omega)$ = complex pressure at point x_o

$|p(x_{ref}, \omega)|^2$ = pressure squared and reference point, x_{ref}
 $= S_{pbl}(\omega)$

The deterministic field joint acceptance can be more easily obtained by calculating

$$Q_m(\omega) = \int_s p(x_o, \omega) \psi_m(x_o) ds$$

then

$$J_{mm}^2(\omega) = \frac{[Q_m(\omega) \quad Q_m^*(\omega)]}{A^2 S_{pbl}(\omega)}$$

Once the generalized force is calculated in the form of joint acceptance, the remainder of the calculations are identical for the deterministic and random formulations.

If the surface mode shapes are given in analytical form, the above integrations are generally accomplished by Gaussian quadrature; however, analytic solutions are used in the program whenever such solutions are available. If the mode shapes are given in Fourier series form, analytical solutions are possible for some pressure field types as follows:

$$\psi_m(x_o) = \sum_p^{mx} \sum_q^{nx} m \beta_{pq} \sin \frac{p\pi x}{xL} \sin \frac{q\pi y}{yL}$$

Substitute into the equations

$$J_{mm}^2(\omega) = \frac{1}{A^2} \sum_p^{mx} \sum_q^{nx} \sum_{p'}^{mx} \sum_{q'}^{nx} m \beta_{pq} m \beta_{p'q'} \left[\int_{s'} \int_s \frac{S_{pbl}(x'_o | x'_o, \omega)}{S_{pbl}(\omega)} \right. \\ \left. \cdot \sin \frac{p\pi x}{xL} \sin \frac{q\pi y}{yL} \sin \frac{p'\pi x'}{xL} \sin \frac{q'\pi y'}{yL} ds ds' \right]$$

$$Q_m(\omega) = \frac{1}{A} \sum_p^{mx} \sum_q^{nx} m \beta_{pq} \left[\int_s p(x_o, \omega) \sin \frac{p\pi x}{xL} \sin \frac{q\pi y}{yL} ds \right]$$

Analytic solutions for the bracketed terms are mandated for computational tractability. The documentation for the program library of external pressure fields is given in appendix C. Point force excitation is among the external pressure, or forcing, fields resident in the library. The routine PRMCAL (see appendix D) provides fully commented directions on the addition of new pressure field types to the source code.

6.10 Prepare Input Data File

At this point, the user should have

1. Become familiar with the basic analytical techniques of the program.
2. Prepared isometric scaled drawing consisting only of surface and subvolume elements to be included in the program element libraries.
3. Identified master surface/subsurface relationships.
4. Numbered each subvolume and numbered each opening.

5. Numbered all surfaces in the correct order (master surfaces + subsurfaces + absorption surfaces).
6. Marked the location of the required nodes on each surface and subvolume on the isometric drawing and numbered the nodes.
7. Updated the modal and SEA element libraries and gathered finite element or experimental modal response information if required.
8. Gathered the relevant structural data on each surface, including the structural damping and acoustic impedance estimates.
9. Selected the external field description for each master surface.

The above information must now be communicated to the program via the Input Data File. Each aspect of the Input Data File is described in detail following the summary of its contents. Recommendations, based on experience with the program, for user-selected parameters are also provided.

In all the options, weak structural/acoustic coupling is assumed. Each option uses the modal analysis method. SEA analysis can be used only with option 1.

Summary of Input Data File

Title

Subtitle

RC A. Option Selection

IOP

(MOP(I), I=1,4)

(IPRE(I), I=1,4)

NPROB, NPROBN, MTAPE, NTAPE

RC B. Sizing Parameters for New Data File

NFV, NFS, NPFCT, NTOBT, NVT, NST, MXVT, MXST, NAMT, NSMT, MXT, NXT, NAMMCT, NSEACT

RC C. Range: Frequency Domain

LBAND, MBAND, IHBAND, BW

RC D. Range: Discrete Frequencies

WI, WF, NWS

RC E. Tolerances

ZERO, EPS

RC F. Matrix Sizing
NN, NS, NMS, MASS, NAS, MXS, NSMX, NSC, NV, MXV, NAM, NTOB, MFE, MX, NX,
NSEAC, NPFC

RC G. Multiple Cavity Parameters
NAMMC, NOO, NOM, IOM, NG, DFQY, NI, ER

RC H. Opening/Volume Relationships
1, NVOL(TAIL), NVOL(HEAD)

NOO, NVOL(TAIL), NVOL(HEAD)

RC I. Opening Description
1, IOTYP(1), AREAD(1), (IOCM(1,I),I+1,MXS)

.
.
.

NOO, IOTYP(NOO), AREAO(NOO), (IOCM(NOO,I),I-1,MXS)

RC J. Structural Data File Access and Storage
(NSDAT(I),I=1,NMS)
(NSTOR(I),I=1,NMS)

RC K. Global Node Points
1, X, Y, Z

.
.
.

NN, X, Y, Z

RC L. Surface Description
1, ISTYP(1), AREA(1), (ISURCM(1,I),I=1,MXS)

.
.
.

NS, ISTYP(NS), AREA(NS), ISURCM(NS,I),I=1,MXS)

RC M. Master Surface/Surface Relationships
1, (MASSUR(1,I),I=1,MNSS)

.
.
.

NMS, (MASSUR(NMS,I),I=1,MNSS)

RC N. Structural Constants: Modal Analysis
1, (SC(1,I),I=1,NSC)

.
.
.

NMS, (SC(NMS,I),I=1,NSC)

(leave off SC if NSDAT(ISUR).NE.O)

RC O. Structural Modal Data

NFEDS

1,IFE(1),NFEN,SL1,SL2),
IF(IFE(1).NE.O)THEN ALSO
(IF(IFEN(J),J=1,NFEN)
(STM(1,K,1),K-1,3),SORG(1,1)
(STM(2,K,1),K-1,3),SORG(2,1)
(STM(3,K,1S),K,1,3),SORG(3,1)

.
.
.
NMS,IFE(NMS),NFEN,SL1,SL2)
IF(IFE(NMS).NE.O)THEN ALSO
(IFEN(J),J=1.NFEN)
(STM(1,K,NMS),K-1,3),SORG(1,NMS)
(STM(2,K,NMS),K-1,3),SORG(2,NMS)
(STM(3,K,NMS),K=1,3),SORG(3,NMS)

NOTE: Full FE data is on a prepared mass storage file (L18). The form of the data on that file is given under the description of file L18 in section 6.7.

RC P. Structural Constants: Statistical Energy Analysis

1, ISEAO(1)
(WMH(J,1), J=1,NSEAC)

.
.
.
(WMH(J,NTOB), J=1,NSEAC)

.
.
.
NMS, ISEAO(NMS)
(WMH(J,1), J=1,NSEAC)

.
.
.
(WMH(J,NTOB), J=1, NSEAC)

RC Q. Volume Description

1, IVTYP(1), V(1), (IVOLCM(1,(), I-1,MXV)

.
.
.
NV, IVTYP(NV), V(NV), (IVOLCM(NV,I), I=1,MXV)

RC R. Acoustic Constants

RO, CO, PREF

RC T. Surface/Volume Relationships
1, ISV(1)

.

.

NS, ISV(NS)

RC S. Acoustic Modal Data

RC U. Surface Absorption
(ZNDATA(I),I=1,NTOP)

IF MOP(3) = 1

-OR-

1, IX IF MOP(3) = 0
(ZNDATA(1,I),I=1,NTOB)

.

.

NS, IX
(ZNDATA(NS,I),I=1,NTOB)

RC V. Structural Damping

1, IX
(ZMDATA(1,I),I=1,NTOB)

.

.

NMS, IX
(ZMDATA(NMS,I),I=1,NTOB)

RC W. External Sound Pressure Level

1, IPF(1)
(SPL(1,I),I=1,NTOB)

.

.

NMS, IPF(NMS)
(SPL(NMS,I),I=1,NTOB)

RC X. External Pressure Field Description

1, IPF(1)
(EX(1,I),I=1,NPFC)

.

.

NMS, IPF(NMS)
(EX(NMS,I),I=1,NPFC)

RC Y. Band Center Frequencies

(CENTF(I),I=1,NTOB)

RC Z. Reverberation Time

The Data Input File has 26 sections lettered A through Z. Each section of data cards is headed by a title card. Each title card begins with a read code. If the code is the integer 1, the program is alerted that the section is to be read. If the code is 0, the program is alerted that there are no cards in that section, and the program therefore will expect the following data card to be the next section's title card. The program options selected by the user determine which data sections are required and which are not. Variables are integer or real by the standard implicit definitions. All data reads are unformatted. Variables on a single card are simply separated by commas. Of course, all variables must be given in a consistent set of units.

A. Option Selection

The option selection requires four data cards. The read code is always 1. The first card is for selection of the type of analysis.

Card A1: IOP - A single integer with

- 1 - Space-averaged, band-averaged pressure squared with random external pressure field excitation.
- 2 - Space-averaged pressure squared at discrete frequencies with random external pressure field excitation.
- 3 - Space-averaged, band-averaged pressure squared with deterministic excitation.
- 4 - Space-averaged pressure squared at discrete frequencies with deterministic excitation.
- 5 - Multiple cavity analysis only.
- 6 - Reverberation time.

The second option selection data card flags miscellaneous options. A "1" activates the option; "0" deactivates the option.

Card A2: MOP(4) - Four integers on the card with

- MOP(1) - Retain mass storage file after execution of program.
- MOP(2) - Suppress printing of the input data.
- MOP(3) - Use experimental cavity damping.
- MOP(4) - Use short BMN calculation on new modal data.

If a data file is to be kept for the problem at hand, set MOP(1)=1. The input data is automatically mirrored to a printer unless MOP(2) is set to 1. If acoustic damping is explicitly known as a function of frequency, it may be entered as data by setting the flag MOP(3) equal to 1. Otherwise it is assumed that the cavity damping must be calculated from surface absorption and acoustic modal characteristics. Finally, if new modal data is to be input, from finite element analysis or experiment, etc., the method of calculating the double sine series representation of the mode shapes can be selected. If MOP(4) is set to 1, then the surface integrations required to calculate the series coefficients will be simple summation of the modal data. Otherwise, a more sophisticated and time-consuming surface integration method will be used.

The third option selection card flags which parameters, if any, are available in the data file. Again, 1 activates the option and 0 deactivates the option.

Card A3: IPRE(4) - Four integers on the card with

IPRE(1) - Acoustic response precalculated.

IPRE(2) - Acoustic absorption precalculated

IPRE(3) - Structural/acoustic interaction, L_{nm} , precalculated for all surfaces.

IPRE(4) - Generalized force or joint acceptance precalculated for all surfaces.

Further details, such as "For which surfaces is the response precalculated?" are given in later sections of the input.

The fourth option selection card gives general data file access and storage information.

Card A4: Four integers on the card with

NPROB - Old problem access number

NPROBN - New problem access number

MTAPE - Old tape access number

NTAPE - New tape access number

If precalculated acoustics are to be used in this run of the program, the problem's reference number must be given. If there is no previous problem, set NPROB to zero. If the important parameters of the problem at hand are to be saved for future use, the problem must be given a reference number. Two tapes are used to eliminate the possibility of a write error destroying the data tape. The data tape, referenced by file number MTAPE, is read into random access mass storage files. During the execution of the program, the random access files are updated with the new data from NPROBN. At the completion of the run, a new tape-- NTAPE--which holds all the previous data and the new data, is created.

B. New Data File Sizing Parameters

The parameters given in this section size the mass storage files. Each parameter is the maximum number allowed for the particular data file. Once these parameters are set for a given data file, they cannot be changed. Any problem placed on the data file may have smaller but never larger values of these parameters. The B card is only read if a new data file is to be created.

Card B1: NFV, NFS NPFCT, NTOBT, NVT, NST, MXVT, MXST, NAMT, NSMT,
MXT, NXT, NAMMCT, NSEACT

NFV - Problems stored on data file

NFS - Structural surface descriptions

NPFCT - Pressure field constants

NTOBT - Frequency bands

NVT - Subvolumes in multiple cavity system

NST - Surfaces in the problem

MXVT - Volume nodes

MXST - Surface nodes

NAMT - Acoustic modes

NSMT - Structural modes

MXT - Largest index in the M direction for Fourier series modal response representation

NXT - Largest index in the N direction for Fourier series modal response representation

NAMMCT - Multiple cavity nodes of importance

NSEACT - Statistical energy analysis constants

The data file is intended to reduce the overall computational requirements of a design concept evaluation or a sensitivity analysis of a particular problem. The preferred values of the constants will therefore depend on the size of the general problem at hand.

C. Range: Frequency Domain

Factors that define the frequency range of the program's calculations are given on the C data card.

Card C: LBAND - Lowest frequency band of interest

MBAND - Band at which SEA assumptions become valid

IHBAND - Highest frequency band of interest

BW - Frequency band width factor (0.12 for one-third octave bands)

where $1 \leq \text{LBAND} \leq \text{MBAND} \leq \text{IHBAND} \leq \text{NTOB}$

The user directs the use of modal and/or statistical energy analysis, when allowed by the option selected, by the selection of LBAND, MBAND, and IHBAND. Between LBAND and MBAND the program uses the modal analysis method. Between MBAND and IHBAND the program uses the statistical energy analysis method if option 1 or 3 was selected. Hence, if MBAND is set equal to IHBAND, only modal analysis is performed. On the other hand, if LBAND is set equal to MBAND only SEA is performed. While the program can handle full octave bands, one-third octave band averaging is recommended.

The selection of MBAND is entirely a function of the internal acoustics of the problem. SEA assumptions become valid at the frequency above which the internal acoustics can be considered reverberant (more than six acoustic modes per one-third octave band). Due to geometry, this frequency is also assumed adequate for SEA descriptions of the structural response. A good estimate of the correct point to shift to SEA can be made by

1. Select the subvolume with the smallest volume.
2. Calculate $f = 1300 / \sqrt[3]{v}$ (with volume, v , in ft^3).
3. MBAND is the band whose center frequency is closest to but not less than f .

MBAND selection in this manner assures that the acoustic field within each subvolume can be considered reverberant. At this point, the SEA analysis can be used to calculate noise levels averaged over each subvolume.

D. Range: Discrete Frequency

Factors that define the range of the program's discrete frequency calculations are given on the D data card.

Card D: WI, WF, NWS

WI - The initial frequency

WF - The final frequency

NWS - The number of frequency steps across range

This data card is needed only when calculation option 2 or 4 is selected.

E. Tolerances

All input tolerances are given on the E card.

E Card: Zero - Value considered 0.0

EPS - Fraction of the maximum contribution from a single mode that can be neglected in the modal summations

EPS is used in the routine BNDCAL to establish structural and acoustic bandwidths of importance for each band. This sophisticated modal summation limiting method assures that only the modes significant in each band are used in the calculations.

F. Matrix Sizing

The matrix sizing establishes, to a great extent, the size of the problem at hand.

F Card: NN - Global node points

NS - Surfaces

NMS - Master surfaces

MNSS - Subsurfaces per master surface

NAS - Absorption surfaces

MXS - Nodes per surface

NSMX - Structural modes per surface
NSC - Structural constants
NV - Subvolumes in system
MXV - Nodes per subvolumne
NAM - Acoustic modes per subvolume
NTOB - One-third octave bands
MFE - Finite element nodes
MX - X-direction Fourier series summation limit
NX - Y-direction Fourier series summation limit
NSEAC - SEA constants
NPFC - Pressure field correlation constants

Parameters NN through MXS are all obtained from the problem drawing as described in section 6.6. The maximum number of structural modes, NSMX, needed for a particular problem depends on both the frequency range of interest and the structures involved in the problem. A good estimate of the NSMX required can be obtained by

1. Select the structure with the lowest natural frequency.
2. Recall the highest frequency band to which the modal analysis will extend (MBAND-1).
3. NSMX is the number of structural resonances below the center frequency of band MBAND.

If only SEA is to be used, set NSMX to zero. The maximum number of structural constants, NSC, is simply a function of the structural types in the modal analysis portion of the problem.

Parameters NV and MXV are obtained from the drawing of the problem as described in section 6.6. The maximum number of acoustic modes, NAM, needed for a particular problem depends on the frequency range of interest and the acoustic subvolumes of the problem. A good estimate of the NAM required can be obtained by

1. Select the largest subvolume of the multiple subvolume system.
2. Recall the highest frequency band to which the modal analysis will extend (MBAND-1).

3. NAM is the number of subvolume acoustic resonances below one and one-half times the MBAND center frequency.

If only SEA is to be used, set NAM to zero. The number of one-third octave bands, NTOB, establishes the maximum range of frequencies the calculations may cover.

The matrix sizing parameters MFE, MX, AND NX have to do with the description of modes with double Fourier series. If modal data is to be given, the maximum number of points at which the mode shape is defined must be provided. MX and MY must be chosen large enough to adequately define the mode shapes over the surface with the double Fourier series. Since the mode shapes are only used in surface integrations, exact replication of the shape is not required. The MX and NX, however, must be sufficiently high to match the number of nodal lines in the highest frequency structural mode to be approximated. The number of SEA constants, NSEAC, and the number of pressure field constants, NPFC, are determined by the structural types and the external pressure field types called out in the problem.

G. Multiple Cavity Parameters

The G card provides the parameters that direct certain aspects of the acoustic component mode synthesis.

G card: NAMMC - Acoustic modes important around exciting frequency

NOO - Openings

NOM - Opening modes

NMO - Total opening modes available

GN - Acoustic modes assumed at some opening mode set

DFQY - Frequency step in natural frequency calculations

NI - Iterations allowed in Newton Raphson convergence on the acoustic natural frequency

ER - Error limits in Newton Raphson iteration

The number of opening modes, NOM, is by far the most important factor in the component mode synthesis computation time requirements. A technique is used to select the most important NOM opening modes from an array of NMO opening modes based on the multiple cavity natural frequency. The evaluation method is executed once for every NG acoustic multiple cavity modes.

H. Opening/Volume Relationships

The opening/volume relationships are used in the generation of the acoustic component mode synthesis equations. There are NOO "H" cards.

H cards: 1 NVOL (tail), NVOL (head)
.
.
.
NOO, NVOL (tail), NVOL (head)

The first integer on each card is the opening number as defined on the problem's drawing (see 6.6). The second integer is the lower subvolume number of the two subvolumes separated by the opening. The third integer is the higher adjacent subvolume number. The subvolumes are also as numbered in section 6.6.

I. Opening Description

The opening element types, area and geometry are needed for the acoustic component mode synthesis.

I cards: 1, IOTYP(1), AREAO(1), (IOCM(1,I), I-1, MXS)
.
.
.
NOO, IOTYP(NO), AREA(NO), (IOCM(NO,I), I-1, MXS)

The first integer on the card is the opening number. The second defines the opening element type from the Program Library of Modal Elements. The third number on each I card is the area of the opening (real number). The final MXS integers are the global node points defining the opening geometry and location. If MXS is greater than the number of nodes required for any particular opening type, place zeros in the unneeded slots.

J. Structural Data File Access and Storage

The mass storage data file, as described in section 6.7.3, holds structural response data calculated in previous computer runs. Each surface on the data file has a unique

reference number. The J cards supplies the data file access and/or storage reference numbers

J card 1: NSDAT(1), ..., NSDAT(NMS)

·
·
·

J card 2: NSTOR(1), ..., NSTOR(NMS)

The first J card gives the data file reference number for each surface of the present problem. If no data exists for a particular surface, a zero is put in that slot. The second J card gives the reference number under which each surface of the present problem will be stored at the completion of the program calculations. Each J card must have NMS integers.

K. Global Node Points

The global node points are used to locate the various volume, opening and surface elements of the problem in global coordinate space. Refer to the scaled drawing with the numbered node points to prepare the K cards.

K cards: 1, X, Y, Z

·
·
·

NN, X, Y, Z

The first entry on each K card is the node number. The next three real numbers are the global X, Y, and Z position of the node.

L. Surface Description

The surface description cards define each surface element of the problem and locates the element in the global coordinate space.

L cards: 1, ISTYP(1), AREA(1), (ISURCM(IS,I),I-1,MXS)

·
·
·

NS, ISTYP(NS), AREA(NS), (ISURCM(NS,I),I-1,MXS)

The first integer on each L card is the surface number as identified on the isometric drawing of the geometry. The next integer, ISTYP(I), is the surface element reference number from the Program Library of Surface Elements. If the surface only inputs power in the SEA frequency range (another master surface is specified to provide the modal analysis data) then enter a zero for ISTYP(I). The surface area, AREA(I), is given next followed by the MXS nodes that locate the element in the global coordinate space. If MXS is greater than the number of nodes required for any particular surface type, place zeros in the unneeded slots. If ISTYP(I) is zero, then place zeros in all the ISURCM slots.

M. Master Surface/Surface Relationships

When a master surface extends over more than one subvolume, subsurfaces are defined. Each subsurface is associated with only one subvolume. The M cards establish the relationships between the master surface and the subsurface.

M cards: 1, (MASSUR(1,I),I-1,MASS)
 .
 .
 .
 NMS, (MASSUR(NMS,I),I-1,MNSS)

The first integer on each M card is the master surface number as established on the isometric drawing of the geometry. The remaining MNSS entries on each card is the surface numbers of the subsurfaces associated with that particular master surface. Zeros are entered in the unneeded data slots. The number of data slots on each card is equal to (1+MNSS).

N. Structural Constants: Modal Analysis

The structural constants needed for the modal response description of each master transmission surface can be provided in this data section.

N cards: 1, SC(1, 1), ..., SC(1,NSC)
 .
 .
 .
 NMS, SC(NMS,1), ..., SC(NMS,NSC)

The first integer on each N card is the surface number as identified on the isometric drawing of the geometry. The remaining NSC entries on each card are the real structural constants. If NSC is greater than the number of constants required for any particular surface type, place zeros in the unneeded data slots. The documentation for the Program Library of Surface Elements defines how many structural constants are needed and in what order they should be supplied. If the surface is already described in the data file (NSDAT(ISUR).NE.O) or (ISTYP(ISUR).EQ.O), then simply insert a card with the master surface number on it, omitting the structural constants.

O. Structural Modal Data

This allows access to a prepared data tape of finite element structural response data.

O cards: NFEDS

```

1,IFE(1),NFEN,SL1,SL2
  IF(IFE(1).NE.O) Read
    (IFEN(J),J=1,NFEN)
    (STM(1,K,1),K=1,d),SORG(1,1)
    (STM(2,K,1),K=1,3),SORG(2,1)
    (STM(3,K,1),K=1,3),SORG(3,1)
    .
    .
    .
NMS,IFE(NMS),NFEN,SL1,SL2
  IF(IFE(NMS).NE.O) read
    (IFEN(J),J=1,NFEN)
    (STM(1,K,NMS),K=1,3),SORG(1,NMS)
    (STM(2,K,NMS),K=1,3),SORG(2,NMS)
    (STM(3,K,NMS),K=1,3),SORG(3,NMS)

```

The integer, NFEDS, indicates the number of sets of finite element data on the data tape. The first integer of the next card is the surface number. The next integer is the data access number for the master surface. If the master surface does not have a finite element description of the mode shapes, a zero is entered. NFEN is the number of nodes associated with the surface. SL1 and SL2 are the x and y dimensions of the surface. Should these factors not apply, enter a zero.

The next four data cards are required only if finite element data is associated with the surface. The array, IFEN(NFEN), holds the node numbers of the finite element data that are associated with the particular surface. The final three cards provide the transformation matrix STM and SORG needed to convert the locations of the finite element nodes from global F.E. coordinates to the local surface coordinate system.

A separate routine generates the data file from either card images or a NASTRAN data tape (output 4 format). This routine, FEPRP, is described in section 6.12. The data file holds the following information for each surface (modal analysis range).

NFEN - Number of finite element nodes
 NSM - Number of structural natural frequencies
 WM(1,NSM) - Natural frequencies
 D1(NFEN) - X-position of each node
 D2(NFEN) - Y-position of each node
 D3(NFEN) - Z-position of each node
 VM(NFEN) - Nodal mass
 SN(NFEN,NSM) - The mode shape value of the three translational degrees of freedom

P. Structural Constants: Statistical Energy Analysis

The structural data needed to complete the SEA response description of each master surface are provided in this section. Since the response description models band averaged type parameters, the SEA structural parameters are given as a function of frequency, a set of constants for each frequency band of interest.

P cards: 1, ISEAO(1) : code card
 (WMH(J(J,1)), J=1,NSEAC) : data cards
 .
 .
 .
 (WMH(J,NTOB),J=1,NSEAC)
 .
 .
 .
 NMS,ISEAO(NMS)
 (WMH(J(J,1)),J=1,NSEAC)
 .

.
.
(WMH(J,NTOB),J=1,NSEAC)

The integer for the ISEAO array identifies the SEA surface type as defined in the documentation for the Program Library of SEA Elements. If the surface is not active in the SEA frequency range then enter a zero for ISEAO(I). If joint acceptance information for the surface has already been calculated (NSDAT(ISUR)≠0) then indicate the surface type on the code card but do not include data cards for the surface. If WMH(1,M) is set to -1, the program will read the remainder of line M then expect the next data card to be a code card.

Q. Volume Description

The volume description cards define each volume element of the problem and locates the element in the global coordinate space.

Q cards: 1,IVTYP(1), V(1), (IVOLCM(1,I),I=1,MXV)

.
.
.
NV, IVTYP(NV), V(NV), (IVOLCM(VN,I),I=1,MXV)

The first integer on each Q card is the volume number as identified on the isometric drawing of the geometry. The next integer, IVTYP(I), is the volume element reference number from the Program Library of Volume Elements. The volume, V(I), of the element is given next, followed by the NXV nodes that locate the element in the global coordinate space. If MXV is greater than the number of nodes required for any particular volume type, place zeros in the unneeded slots.

R. Acoustic Constants

The acoustic constants needed to complete the acoustic response description are provided in this data section.

R cards: RO - Density of the fluid

CO - Speed of sound in the fluid

PREF - Reference pressure for calculation of decibels

S. Acoustic Modal Data

T. Surface/Volume Relationships

A master surface may or may not be associated with a single subvolume. All other surfaces, the subsurfaces and absorption surfaces are, by definition, adjacent to only one subvolume. The S cards define these relationships.

S cards: 1, ISV(1)

⋮

NS, ISV(NS)

The first integer on each S card is the surface number as defined on the isometric drawing of the geometry. The second integer is the number of the subvolume that is adjacent to the indicated surface. If the surface is a master surface that extends over two or more subvolumes, enter a zero.

U. Surface Absorption

The wall impedance is given in the data in terms of the absorption coefficient:

$$\alpha \equiv 8 \rho c / Z_a$$

where Z_a is the normal surface impedance.

U card: 1, IX

- code card

(ZMDATA(1,I),I=1,NTOB)

- data card

⋮

NS, IX

- code card

(ZMDATA(NS,I),I=1,NTOB)

- data card

The absorption coefficient for each surface and for each frequency band is given. The IX is a code that directs the following read options:

IX = 0 Then the surface is a master surface with subsurfaces. The read skips to the next code card.

IX - 1 Read the data card.

The modal analysis equations use the surface impedance data and along with the acoustic mode shape information to calculate the acoustic modal cavity damping. If the option MOP(3)=1 is selected, the acoustic cavity damping is provided as data. This data is entered in place of the first surface's impedance data.

In the SEA calculations, the program uses the surface absorption coefficient to calculate the power absorbed by the surface. Note that acoustic damping information must be provided for the entire frequency range of interest (frequency band 1 to band NTOB).

For ease of data entry, the wall impedance will be entered in terms of absorption coefficient defined as

$$\alpha \equiv 8 \rho c / Z_a$$

In the SEA calculations, the program will use this factor directly. In the modal analysis calculations, the program will use the value to calculate the cavity damping factor.

V. Structural Damping

The internal energy dissipation characteristics, or damping, of each master transmission surface must be given as a function of frequency.

V card: 1, IX	- code card
(ZMDATA(I),I=1,NTOB)	- data card
.	
.	
.	
NMS, IX	- code card
(ZMDATA(I),I=1,NTOB)	- data card

The first integer of the code card identifies the master surface. The IX is a code that directs the following read options:

- IX = 0 Skip to next code card. The mass storage data is good for this surface.
- IX = 1 Read the new data card and replace over the old data in mass storage, if any.

The damping is given in terms of C/C_c , or percent of critical damping.

W. External Sound Pressure Level: Frequency Domain

The reference sound pressure level of the exterior side of each master transmission surface is provided as a function of frequency. The reference SPL is the band-limited perturbation pressure squared at the centroid of the master transmission surface. The level must be expressed in decibels with the reference pressure as given by the "R" input card. A later section will describe the relationship of the pressures at other points on the surface to the reference pressure.

W cards: 1, IX	- code card
(SPL(I), I=1, NTOB)	- data card
.	
.	
.	
NMS, IX	- code card
(SPL(I) I=1, NTOB)	- data card

The IX is a code that directs the following read options:

IX = 0 Use SPL data already in mass storage for this surface.

IX = 1 Read the new data card and replace over the old data in mass storage.

X. External Pressure Field Description

Several types of external pressure fields are held in the Program Library of External Pressure Fields. The constants needed to complete the description of the pressure field are provided for each surface.

X cards: 1, IPF(1)	- code card
(EX(1, I), I=1, NPFC)	- data card
.	
.	
.	
NMS, IPF(NMS)	- code card
(EX(NMS, I), I=1, NPFC)	- data card

The first integer of each data set is the number of the master transmission surface. This is followed by the pressure field reference number, which defines the

type of external pressure field for that master transmission surface. If mass storage data is available, place a zero for the field type and skip to the next code card. The second card in each set gives the constants as defined in the Library of External Pressure Fields. The various external pressure fields over a surface can be random or deterministic and described in the frequency domain. It can also be deterministic and described in the time domain. The type of external pressure field description available for the problem often determines the type of analysis that must be conducted.

Y. Band Center Frequencies

The center frequencies of each band are given for the range of interest.

Y cards: (CENTF(I), I=1, NTOB)

The frequencies must be given cycles per second. The program converts these more common units to radians per second for calculations.

Z. Reverberation Time

This section gives access to a specialized routine included in VIN for the calculation of a cavity's reverberation time. Reverberation time is defined as the time required for the diffuse pressure in a room to decay 60 dB after the pressure-generating source is turned off.

Z cards: IC, DT

The integer IC specifies the type of reverberation calculation to be made. Enter a 1, and REVERB calculates the overall reverberation time. Enter a 2, and the band-limited reverberation time is calculated. DT is the time step for either selection.

6.11 Executive Commands

Executive commands for program collection, mass storage file management, and data tape management have been combined into several program files. The user may select the program file with the command series desired.

@ RUN	- required
@ ADD, P XX.DEL	- optional
@ ADD, P XX.TAPIN	- optional

@ ADD, P XX.SOURCE	- required
@ ADD, P XX.DATA	- required
@ ADD, P XX.EXTND	- optional
@ ADD, P XX.TAPOT	- optional
@ FIN	- required

Required RUN card is filled out in accordance with site requirements

Optional XX.DEL deletes all cataloged program files with the names, L0, L1, ..., L18.

Optional XX.TAPIN represents a series of tape management commands left to the user since the commands may vary from site to site. These commands should load saved mass storage data back into mass storage. A sample XX.TAPIN run stream is given in appendix D along with the program listing.

Required XX.SOURCE must be one of the following:

XX.SOURC1

1. Recompiles and maps all program routines
2. Starts program execution

XX.SOURC2

1. Assumes program already compiled and starts program execution

Required XX.DATA is the input data file as fully described in section 6.

Optional XX.EXTND extends the cataloged data files L0 through L18 for 8-day retention by system. (Univac 1108 Marshall Space Flight Center, Huntsville, Alabama, system.)

Optional XX.TAPOT represents a series of tape management commands left to the user. The commands should load mass storage files L0 through L18 onto tape in bulk. A sample TAPOT series is given with the program listing in appendix D.

Required FIN card completes the run in batch mode.

6.12 Finite Element Data File Preparation

A program, referred to here as FEPRP, is required to load the finite element data file L18. Refer to the description of file L18 in section 6.7 for the required format. Since

many finite element programs are available, each with several output options, the user has been left the responsibility for this aspect of the data input preparation. For illustrative purposes, however, an FEPRP routine for NASTRAN output capabilities has been written. The commented routine is given in appendix D.

Section 7

APPLICATION TO SPACE SHUTTLE PAYLOAD BAY

The general purpose structural/acoustic interaction model, VIN, was used in the analysis of the Space Shuttle payload bay noise transmission problem. Three specific cases were modeled: the OV-101 jet noise test case with empty payload bay, the OV-101 jet noise test case with Spacelab-2 payload, and the STS-2 launch.

On January 31, 1977, at Edwards Air Force Base, an acoustic test, using two jet aircraft as the acoustic source, was performed on the OV-101. This well-documented test provides the best means available to evaluate the structural and acoustic models developed for the empty Space Shuttle payload bay.

The structural model for the modal analysis calculations is derived from a finite element analysis and some "interpretation" of this data.⁽¹⁵⁾ The structural finite element data spanned the entire modal analysis frequency range (0-80 Hz). The structural model for the statistical energy analysis calculations was adapted from that developed for NASA in reference 3. The SEA model in reference 3 included the bottom, sidewall, bulkhead, and payload bay door structures. Since the payload bay doors dominate the acoustic power input to the cavity, the structural model implemented in VIN assumes the bottom, sidewall and bulkhead to be rigid.

The predictions of the significantly simplified structural model implemented in VIN, the predictions of the model of reference 3, and experimental results are shown in figure 8. The shaded area indicates the band of possible experimental error. More precisely, deviations of predicted levels from the experimental value within the band indicated are not statistically significant at the 1% level of significance.⁽¹⁶⁾ By this criterion, the simplified model used in the calculations by VIN can be considered as valid as the more complex model of reference 3. In essence, the interior noise predictions in the SEA region have a single driver, the payload bay doors. Details of the structural model development are presented in depth in the references.^(3, 15) A complete input data file for the test case is given in appendix E. It should be noted that the final door model parameters were chosen to force fit the experimental noise data. Model predictions

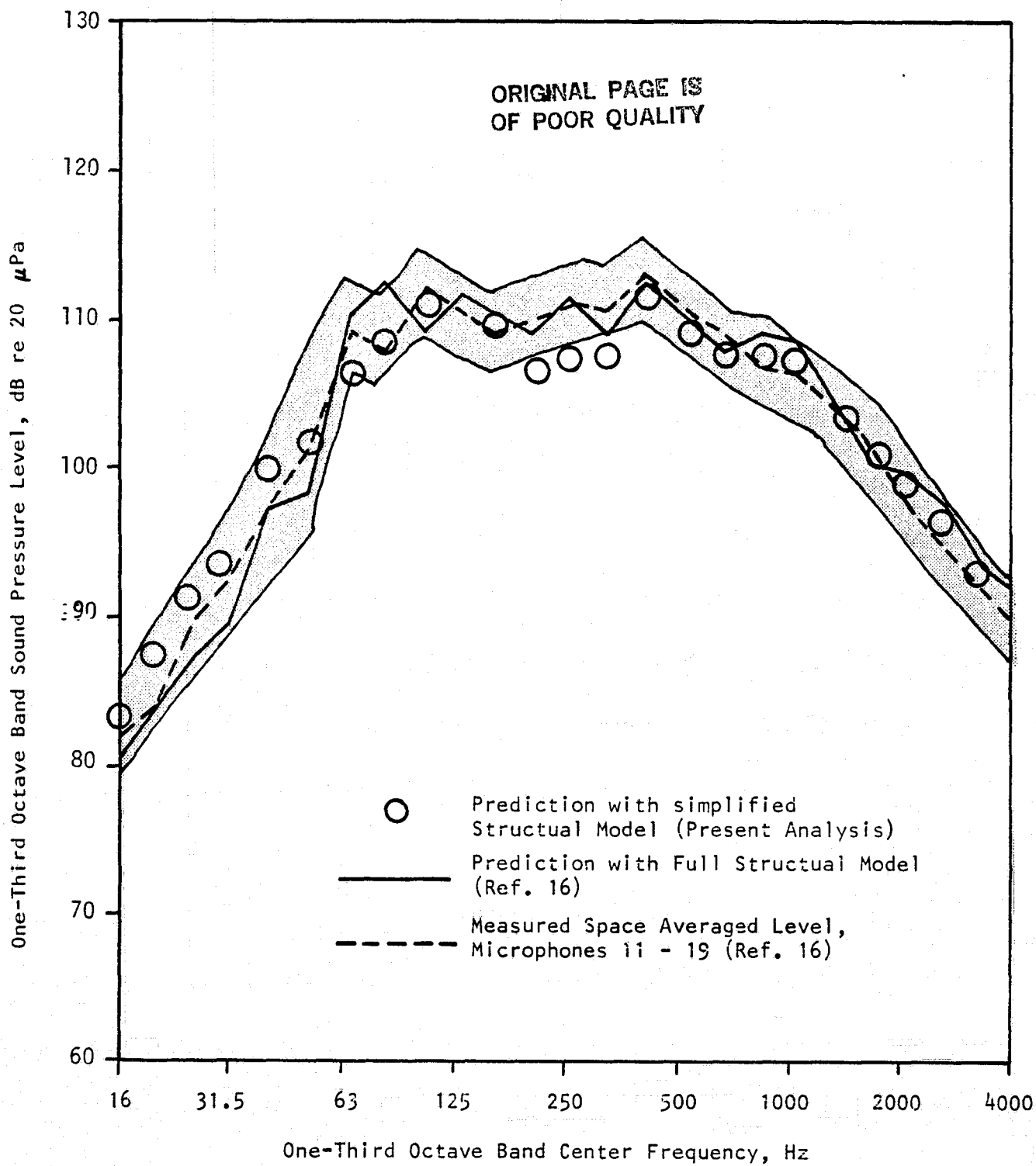


Figure 8. Measured and Predicted Payload Bay Acoustic Levels for OV-101, Tests 2 and 3

based on the initial (pre-experiment) and final (post-experiment) door models are given in figure 9. This particular figure gives clear evidence of the extreme difficulty, if not impossibility, of accurately modeling the high frequency behavior of complex structures without structure-specific test data.

Scale model tests were also conducted for NASA to examine the effects of payloads on the average payload bay noise levels.⁽¹⁷⁾ The Spacelab-2 payload was one of the several configurations tested. Some of the experimental results are shown in figure 10.

The addition of a payload has several effects on the acoustic response characteristics of the payload bay. A payload reduces the volume of the acoustic space; it alters the mode shapes of the volume; and it increases the overall acoustic absorption of the payload bay. A decrease in volume tends to increase the noise level. A change in acoustic mode shapes will generally have little effect on the overall noise level in the volume if the excitation is broadband. It may, however, cause large one-third octave band level changes. An increase in acoustic absorption, of course, tends to decrease the noise level.

The analytical models implemented in VIN are theoretically capable of representing these effects. As a practical matter, however, accurate quantitative predictions were not achieved. In the low frequency regime, the complexity of the acoustic space around the Spacelab-2 payload was beyond the ability of the component mode synthesis to accurately model. In both the modal and SEA calculations, payload absorption estimates had to be made based on data with an order of magnitude of scatter (see reference 17). While it is clear that reasonable numbers could be chosen that would force a fairly good match of the experimental results of figure 10, such an exercise is considered meaningless.

Finally, the interior payload bay noise level for the STS-2 flight launch conditions was predicted. Comparison with flight data is given in figure 11. The structural model remained as previously described except for an increase in payload bay door mass to represent the addition of the thermal protection system. The input data file for this case is listed in appendix E. The predictions are in reasonable agreement with flight data considering the statistical variability associated with the small number of internal and external microphone measurements.

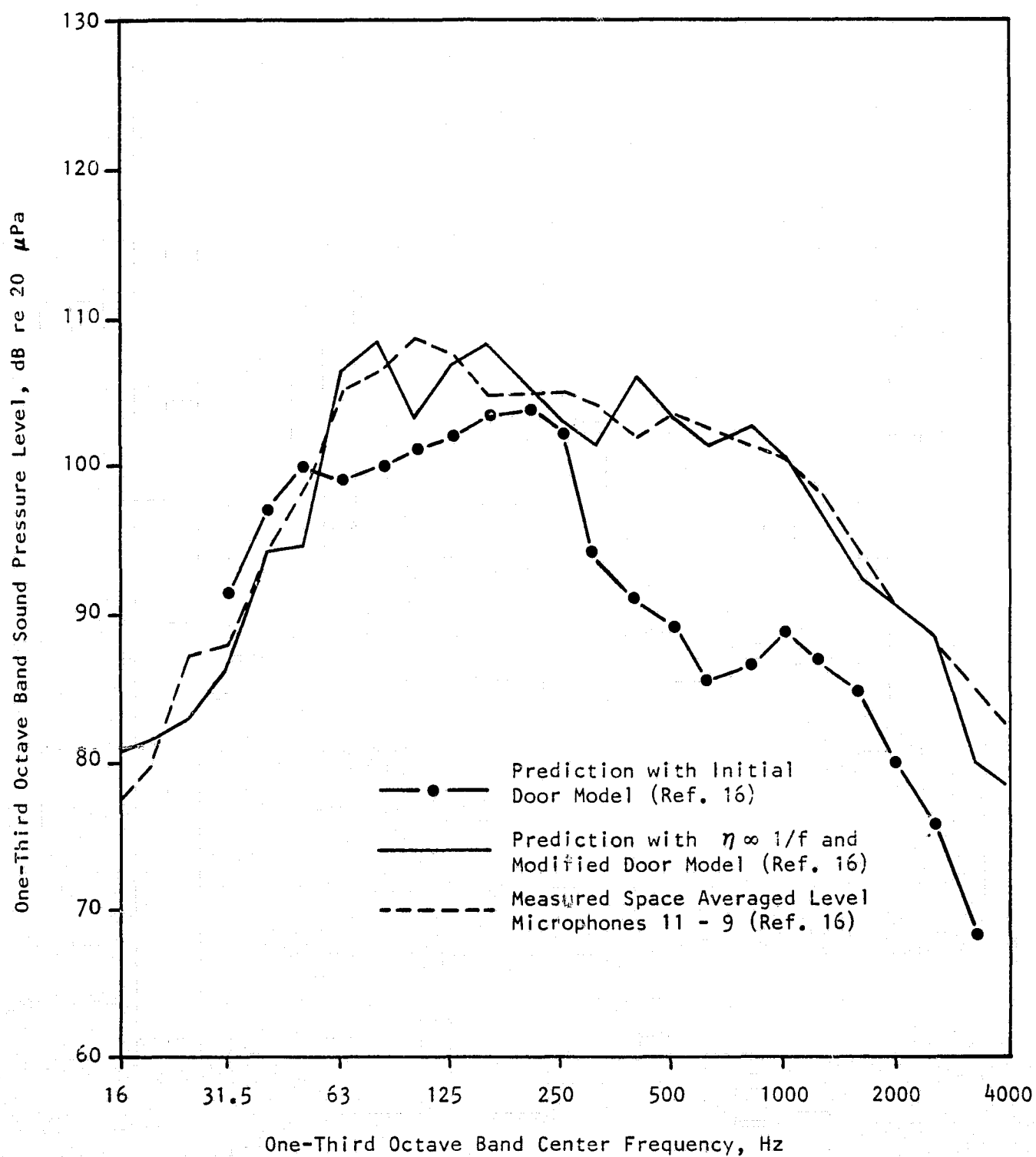


Figure 9. Noise Predictions of Alternate Door Models
for OV-101, Test 4

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OF POOR QUALITY

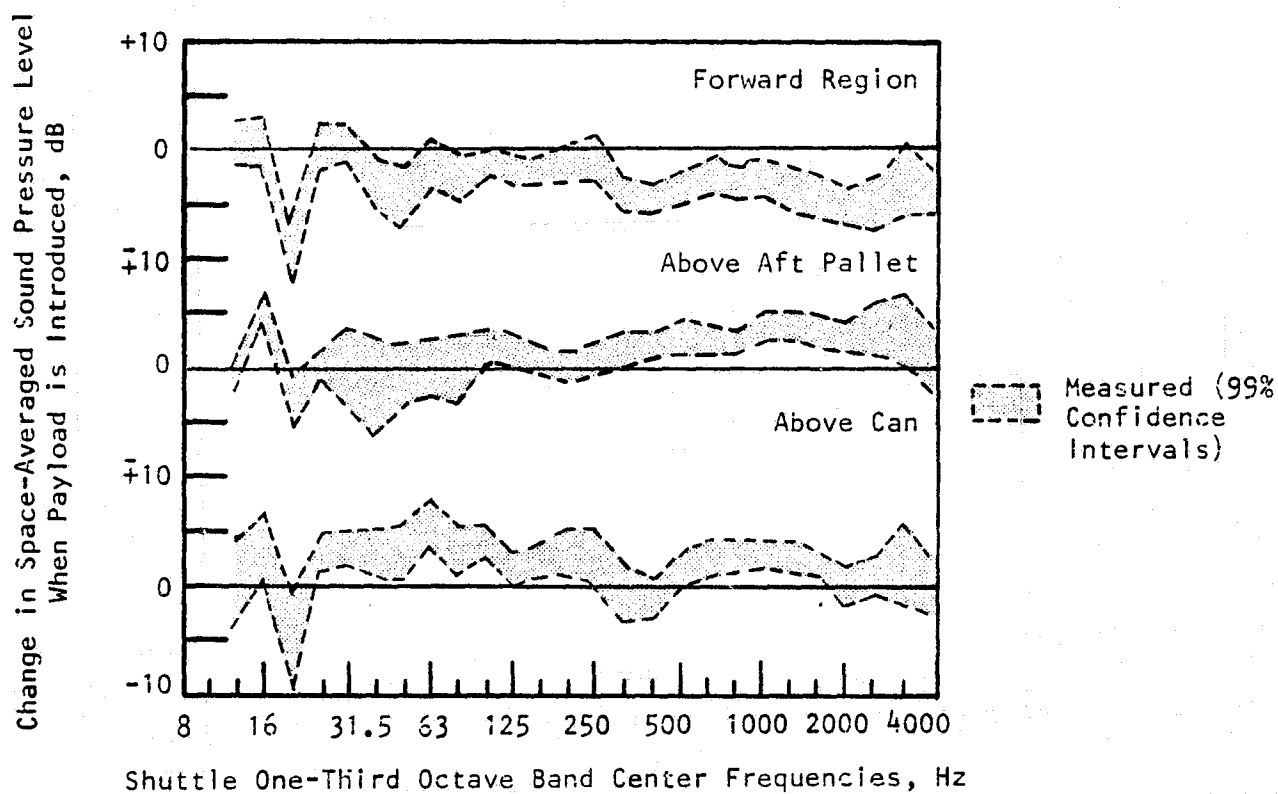


Figure 10. Comparison of Predicted and Measured Changes in Sound Levels, Spacelab-2 Payload Model

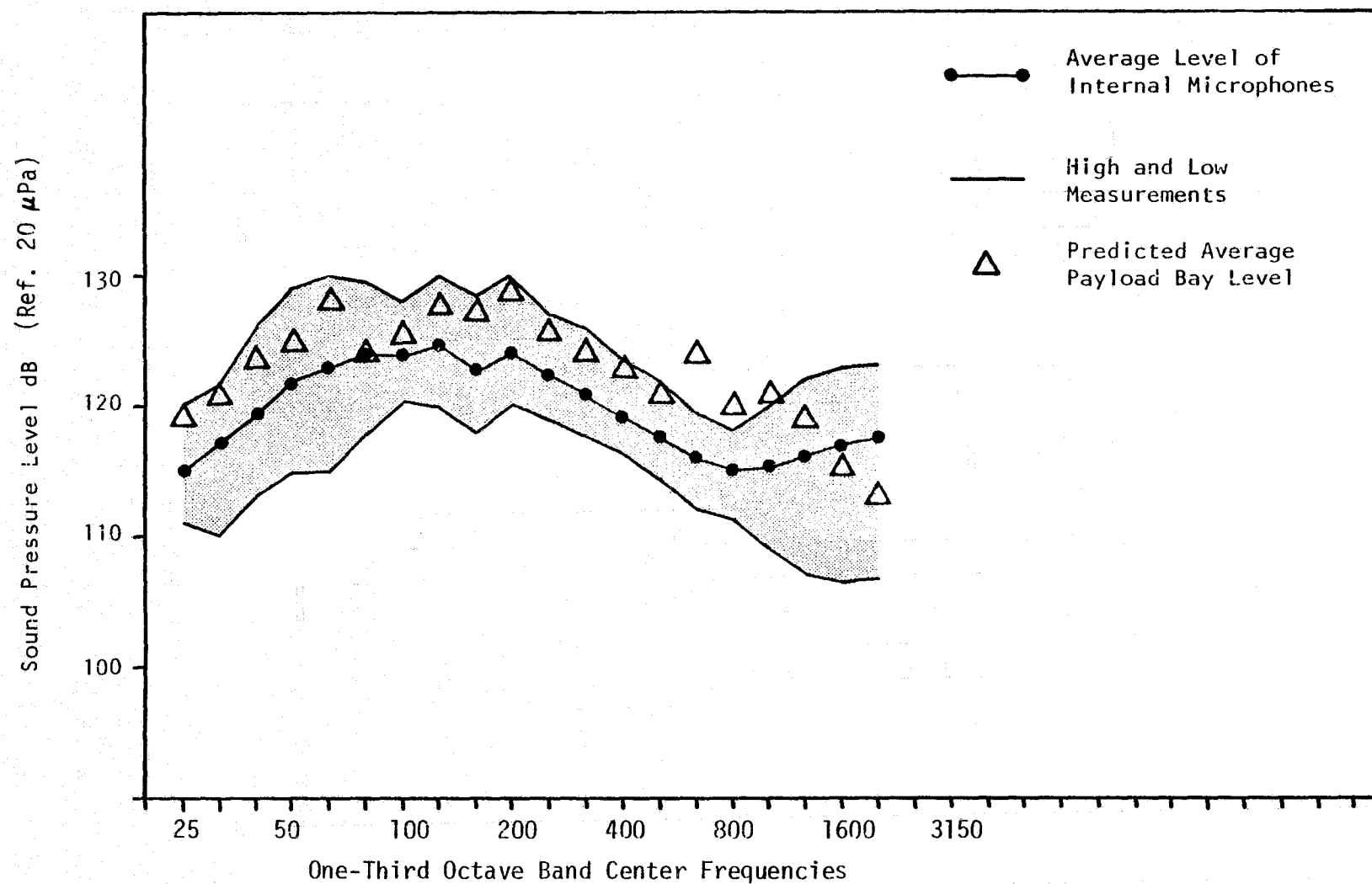


Figure 11. Measured and Predicted Payload Bay Acoustic Levels for STS-2 Liftoff (data 6-12 seconds after ignition)

Section 8

SUMMARY

A general purpose computer program was developed for the prediction of vehicle interior noise. This program, named VIN, has both modal and statistical energy analysis capabilities for structural/acoustic interaction analysis.

The analytical models and their computer implementation were verified through simple test cases with well-defined experimental results. The model was also applied in a Space Shuttle payload bay launch acoustics prediction study.

The computer program will process large and small problems with equal efficiency because all arrays are dynamically sized by program input variables at run time. A data base can be built and easily accessed for design studies. The data base significantly reduces the computational costs of such studies by allowing the reuse of the still-valid calculated parameters of previous iterations. Given accurate structural and acoustic response and exterior acoustic field data, the program will yield reliable results. The problem facing the program user will be the determination of the input data. Except for the most simple cases, finite element or experimental structural data will probably be needed for the modal analysis portion of the program. The acoustic component mode synthesis capability of the program makes the determination of the modal analysis range acoustic response less of a problem. For the SEA model, the estimation of the statistical energy analysis parameters, such as the joint acceptance, is required. The joint acceptance includes or is implicitly coupled with structural mode shape information, structural modal density, and external (and internal) pressure distribution estimation. The combined complexity of these factors usually limit the SEA method to rough design trend studies or a post-test semiempirical modeling role. In any case, the general purpose program VIN provides the framework needed to make use of the full capabilities of both the modal analysis and SEA methods for vehicle interior noise predictions.

Section 9

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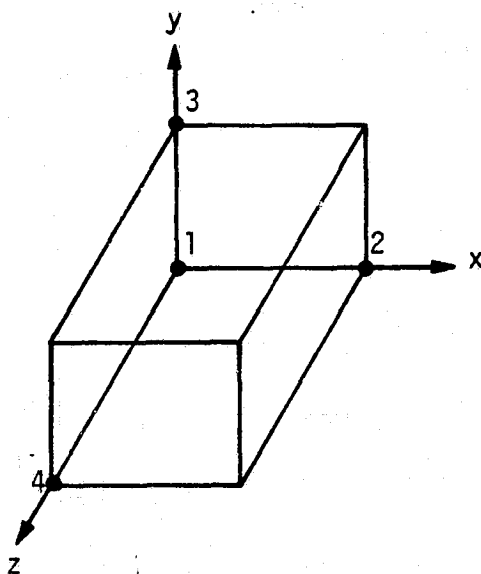
APPENDIX A

PROGRAM LIBRARY OF MODAL ELEMENTS

PART I. VOLUME ELEMENTS

1a. Volume Type 1: Parallelepiped

1b. Shape



1c. Natural Frequency Equation

$$\omega_{mns} = C_0 \pi \left(\left(\frac{m}{xL} \right)^2 + \left(\frac{n}{yL} \right)^2 + \left(\frac{s}{zL} \right)^2 \right)^{1/2}$$

where

C_0 - speed of sound in fluid

m, n, s - integer indexes for x-, y-, and z-directions, respectively

xL - length of parallelepiped in x-direction

yL - length of parallelepiped in y-direction

zL - length of parallelepiped in z-direction

1d. Mode Shape Equation

$$F_{mns}(x,y,z) = \left(\cos \frac{m\pi x}{XL} \cos \frac{n\pi y}{YL} \cos \frac{s\pi z}{ZL} \right) / D_{mns}$$

where

$$D_{mns} = \left(\frac{\epsilon_m \epsilon_n \epsilon_s}{8} \right)^{1/2}$$

$$\begin{aligned} \epsilon_m &= 1 \text{ if } m = 1 \\ &= 2 \text{ if } m = 0 \end{aligned}$$

$$\begin{aligned} \epsilon_n &= 1 \text{ if } n = 1 \\ &= 2 \text{ if } n = 0 \end{aligned}$$

$$\begin{aligned} \epsilon_s &= 1 \text{ if } s = 1 \\ &= 2 \text{ if } s = 0 \end{aligned}$$

With D_{mns} calculated in this manner, the acoustic generalized mass

$$M_{mns} = \frac{1}{V} \int_V F_n^2(x,y,z) dV = 1.0$$

1e. Summary of Program Variables Associated with Volume Element Description

NVOL - assigned volume number

OVTYP(NVOL) - volume type

(VNODC(1,J,NVOL),J=1,3) - x, y, z coordinates of node 1

(VNODC(2,J,NVOL),J=1,3) - x, y, z coordinates of node 2

(VNODC(3,J,NVOL),J=1,3) - x, y, z coordinates of node 3

(VNODC(4,J,NVOL),J=1,3) - x, y, z coordinates of node 4

C_o - speed of sound in contained fluid

XL,YL,ZL - primary lengths of parallelepiped calculated from the node points

WN(1,NWN,NVOL) - natural frequency of volume mode NWN

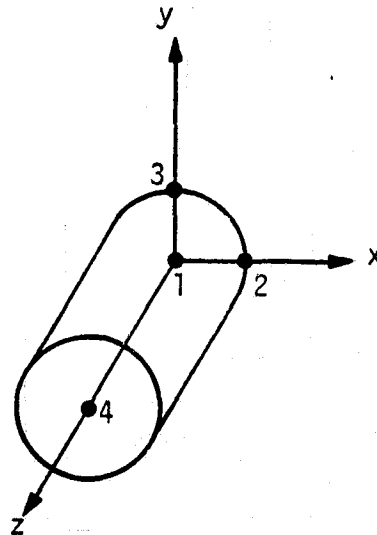
WN(2,NWN,NVOL) - modal index m of volume mode

WN(3,NWN,NVOL) - modal index n of volume mode NWN

WN(4,NWN,NVOL) - modal index s of volume mode NWN

2a. Volume Type 2: Circular Cylinder

2b. Shape



2c. Natural Frequency Equation

$$\omega_{mns} = c_0 \left(\left(\frac{s\pi}{zL} \right)^2 + K_{nm}^2 \right)^{1/2}$$

where K_{nm} is calculated by the solution to the equation:

$$J_n'(K_{nm} \cdot a) = 0$$

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and $J_n(x)$ - Bessel function of the first kind

a - radius of cylinder

m, n, s - integer mode numbers of the r, θ, z -directions, respectively

zL - length of cylinder along z -axis

C_0 - speed of sound in fluid in the volume

K_{nm} - allowed frequency constant

2d. Mode Shape Equation

$$r = (x^2 + y^2)^{1/2}$$

$$\theta = \cos^{-1}(x/r)$$

$$z = z$$

$$K_{nm} = (\omega_{mns}^2 / C_0^2 - (s\pi/zL)^2)^{1/2}$$

MODE SHAPE,

$$F_{mns}(r, \theta, z) = \cos\left(\frac{s\pi z}{zL}\right) \cos(n\theta) J_n(K_{nm} \cdot r) / D_{mns}$$

WHERE D_{mns} IS CHOSEN SUCH THAT THE GENERALIZED MASS

$$\frac{1}{V} \int_V F_{mns}^2(r, \theta, z) dv = 1.0$$

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$$D_{mns} = \left\{ \left(\frac{\epsilon_s \epsilon_1}{4} \right) \left(J_n'^2(K_{nm} a) \right) + \left(1 - \frac{n^2}{K_{nm}^2 a^2} \right) J_n^2(K_{nm} a) \right\}^{1/2}$$

and $J_n'(x)$ = first derivative of the Bessel function $J_n(x)$

$$\epsilon_s = 1 \text{ if } s = 0$$

$$= 2 \text{ if } s = 1$$

$$\epsilon_n = 1 \text{ if } n = 0$$

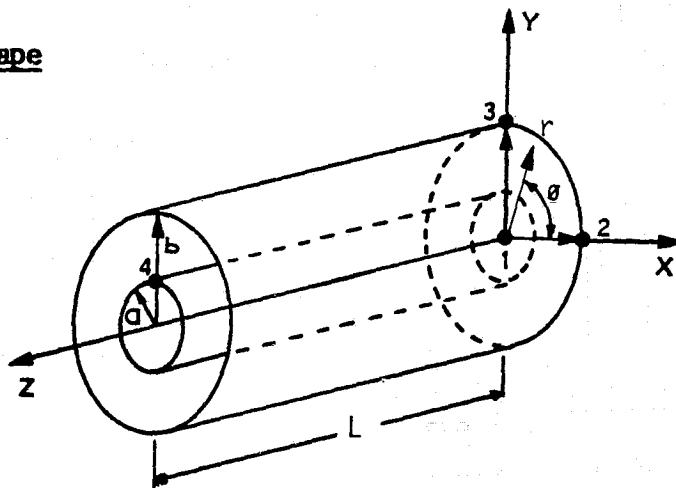
$$= 2 \text{ if } n = 1$$

2e. Summary of Program Variables Associated With the Volume Element Description

See section e of volume element 1.

3a. Volume Type 3: Concentric Circular Cylinders

3b. Shape



3c. Natural Frequency Equation

$$\omega_{mns} = \omega_0 \left(\left(\frac{s\pi}{2L} \right)^2 + K_{nm}^2 \right)^{1/2}$$

C_o - speed of sound in the fluid in the volume

zL - length of concentric cylinder

mns - modal indexes for the r -, θ -, z -directions respectively

a - inside radius

b - outside radius

r - radius to some point in the volume

K_{nm} - allowed frequency constant

and K_{nm} is the roots of the equation

$$Q'_n(K_{nm}a) = 0$$

with

$$Q_n(K_{nm}a) = J_n(K_{nm}a) - \frac{J'_n(K_{nm}b)}{Y'_n(K_{nm}b)} Y_n(K_{nm}a)$$

$J_n(x)$ - Bessel function of the first kind

$Y_n(x)$ - Bessel function of the second kind

3d. Mode Shape Equation

$$r = (x^2 + y^2)^{1/2}$$

$$\theta = \cos^{-1}(x/r)$$

$$z = z$$

$$K_{nm} = (\omega_{mns}^2 / C_o^2 - (S\pi / zL)^2)^{1/2}$$

$$F_{mns}(r, \theta, z) = \cos\left(\frac{S\pi}{zL}\right) \cos(n\theta) Q_n(K_{nm}r) / D_{mns}$$

where

$$Q_n(K_{nm} r) = J_n(K_{nm} r) - \frac{J_n'(K_{nm} b)}{Y_n'(K_{nm} b)} Y_n(K_{nm} r)$$

and D_{mns} is chosen such that the generalized mass

$$M_{mns} = \frac{1}{V} \int_V F_{mns}^2(r, \theta, z) dV = 1.0$$

$$D_{mns} = \left\{ \left(\frac{\epsilon_s \epsilon_n}{4} \right) \left(\left(b^2 - \frac{n^2}{K_{nm}^2} \right) Q_{nm}^2(K_{nm} b) - \left(a^2 - \frac{n^2}{K_{nm}^2} \right) Q_{nm}^2(K_{nm} a) \right) \right\}^{1/2}$$

where

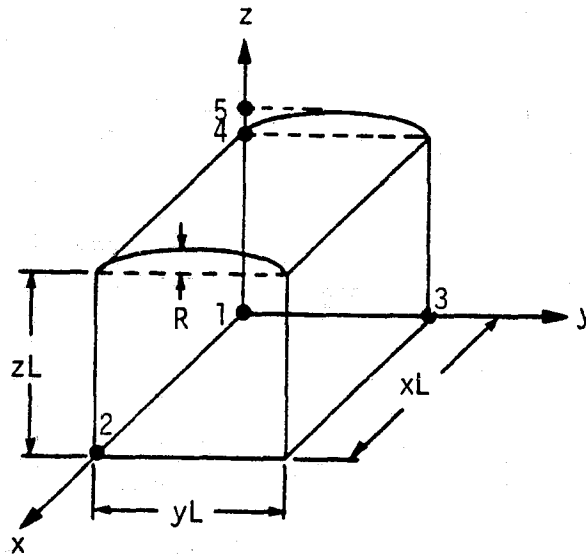
$$\begin{aligned} \epsilon_s &= 1 \text{ if } s = 1 \\ &= 2 \text{ if } s = 0 \\ \epsilon_n &= 1 \text{ if } n = 1 \\ &= 2 \text{ if } n = 0 \end{aligned}$$

3e. Summary of Program Variables Associated With the Volume Element Description

See section e of volume element 1.

4a. Volume Type 4: Deformed Rectangular Parallelepiped

4b. Shape



4c. Natural Frequency

$$\omega_{mns} = \omega_0 \omega_{mns} \left(1 + 2 \varepsilon \gamma_{ns} \left(\left(\frac{n\pi}{yL} \right)^2 + \left(\frac{s\pi}{zL} \right)^2 \right) / \omega_{mns}^2 \right)^{1/2}$$

WHERE

$$\omega_{mns}^0 = \left(\left(\frac{m\pi}{xL} \right)^2 + \left(\frac{n\pi}{yL} \right)^2 + \left(\frac{s\pi}{zL} \right)^2 \right)^{1/2}$$

$$\varepsilon = R/zL$$

FOR $n, s > 0$

$$\gamma_{ns} = \left(\frac{-2 s^2 \pi^2}{zL^2} \left(\frac{1}{3} - \frac{1}{n^2 \pi^2} \right) - \frac{4}{yL^2} \right) / \left(\left(\frac{n\pi}{yL} \right)^2 + \left(\frac{s\pi}{zL} \right)^2 \right)$$

For $n=0, s>0$

$$V_{sn} = \left(-\frac{2s^2\pi^2}{zL^2} \left(\frac{2}{3} \right) - \frac{4}{yL^2} \right) / \left(\frac{s\pi}{zL} \right)^2$$

For $n=0, s=0$

$$V_{sn} = 0$$

C_0 - speed of sound of the fluid in the parallelepiped.

4d. Mode Shape Equations

The deformed parallelepiped's mode shape will be approximated by that of a simple parallelepiped

$$F_{mns}(x, y, z) = \left(\cos \frac{m\pi x}{Lx} \cos \frac{n\pi y}{Ly} \cos \frac{s\pi z}{Lz} \right) / D_{mns}$$

where

$$D_{mns} = \left(\frac{\epsilon_m \epsilon_n \epsilon_s}{8} \right)^{1/2}$$

and

$$\begin{aligned} \epsilon_m &= 1; m = 1 \\ &= 2; m = 0 \end{aligned}$$

$$\begin{aligned} \epsilon_n &= 1; n = 1 \\ &= 2; n = 0 \end{aligned}$$

$$\begin{aligned} \epsilon_s &= 1; s = 1 \\ &= 2; s = 0 \end{aligned}$$

D_{mns} calculated in this manner forces the acoustic generalized mass:

$$M_{mns} = \frac{1}{V} \int_V F_n^2(x,y,z) dV = 1.0$$

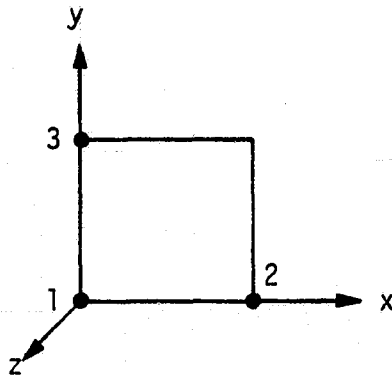
4e. Summary of Program Variables Associated With the Volume Element Description

See section 3 of volume element 1.

PART II. OPENING ELEMENTS

1a. Opening Type 1: Rectangle

1b. Shape



1c. Mode Shape Equation

$$\text{FACTOR FOR MODE ORDERING} = \left(\left(\frac{p}{x_s} \right)^2 + \left(\frac{q}{y_s} \right)^2 \right)$$

$$\psi_{pq}(x,y) = \cos \frac{p\pi x}{x_s} \cos \frac{q\pi y}{y_s}$$

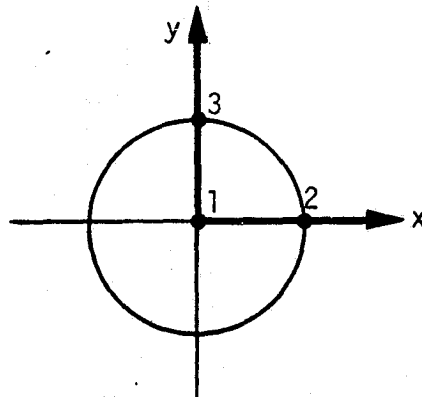
where x_s - length of panel in x-direction
 y_s - length of panel in y-direction
 p, q - modal index in the x- and y-directions respectively

1d. Summary of Program Arrays Associated With the Opening Description

- IOTYP(NOO) - opening element type declarations
- ONODC(MXS,3,NOO) - array holding node points
- WMO(1,MWM,ISUR) - frequency factor of opening mode MWM
- WMO(2,MWM,ISUR) - modal index p of opening mode MWM
- WMO(3,MWM,ISUR) - modal index q of opening mode MWM

2a. Opening Type 2: Circle

2b. Shape



2c. Mode Shape Equation

FACTOR FOR MODE ORDERING = K_{gp}

$$\psi_{pg}(r, \theta) = \cos(g\theta) J_g(K_{gp} r)$$

a - radius of opening

$J_q(x)$ - Bessel function of the first kind

q, p - mode numbers

K_{qp} - allowed frequency constant such that

$$J_q(K_{qp} a) = 0$$

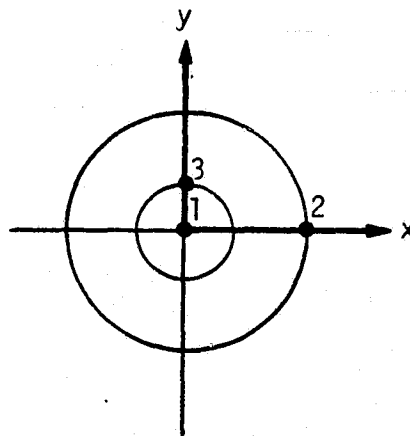
WHEN p IS LARGE, $K_{p3} = (p + 3/2 - 1/4) (\pi/a)$

2d. Summary of Program Variables Associated With Opening Element Description

See section d of opening element type 1.

3a. Opening Type 3: Concentric Circle

3b. Shape



3c. Mode Shape Equation

FACTOR FOR MODE ORDERING = K_{3p}

$$\psi_{p3}(r, \theta) = \cos(3\theta) Q_3(K_{3p} r)$$

where

$$Q_3(K_{3p} r) = J_3(K_{3p} r) - \frac{J_3'(K_{3p} b)}{Y_3'(K_{3p} b)} Y_3(K_{3p} r)$$

p, q - modal indexes for r - and θ -directions respectively

a - inside radius of opening

b - outside radius of opening

$J_q(x)$ - Bessel function of the first kind

$Y_q(x)$ - Bessel function of the second kind

$J'_q(x)$ - first derivative of the Bessel function of the first kind

$Y'_q(x)$ - first derivative of the Bessel function of the second kind

K_{qp} - allowed frequency factor such that

$$Q'_q(K_{qp} a) = 0.0$$

and $Q'_q(x)$ is the derivative of $Q_q(x)$.

3d. Summary of Program Variables Associated With Opening Element Description

See section d of opening type 1.

PART III. ANALYTIC OPENING/VOLUME COUPLING, L_{nm}

1. Opening Type 1/Volume Type 1: Rectangle/Parallelepiped

This analytic solution assumes the opening lies on a surface of the volume with the sides of the opening square with the surface of the parallelepiped sides.

$$L_{nm} = \frac{1}{A} \int_0^{ys} \int_0^{xs} F_n(x', y', z') \psi_m(x, y) dx dy$$

Let

A - area of opening

x' - $x - a$

y' - $y - b$

z' - $z - c$

n - represents the three acoustic indexes

m - represents the two opening indexes

a, b, c - coordinate transformation constants

xs, ys - length of the sides of the opening

xv, yv, zv - length of the sides of the parallelepiped (Note that xs corresponds in direction to xv and ys to yv .)

$$F_n(x', y', z') = \cos \frac{j\pi x}{xv} \cos \frac{j\pi y}{yv} \cos \frac{k\pi z}{zv}$$

$$\psi_m(x, y) = \cos \frac{p\pi x}{xs} \cos \frac{q\pi y}{ys}$$

HENCE

$$\begin{aligned} L_{nm} &= \frac{1}{A} \cos \frac{k\pi(z-c)}{zv} \int_0^{xs} \cos \frac{j\pi(x-a)}{xv} \cos \frac{p\pi x}{xs} dx \\ &\quad \cdot \int_0^{ys} \cos \frac{j\pi(y-b)}{yv} \cos \frac{q\pi y}{ys} dy \\ &= \frac{1}{A} \cos \frac{k\pi(z-c)}{zv} \cdot XI \cdot YI \end{aligned}$$

WHERE

$$\text{IF } xv = xs \text{ AND } i+p = 0 \quad ; \quad XI = xs$$

$$\text{IF } xv = xs \text{ AND } i-p \neq 0 \quad ; \quad XI = 0$$

$$\text{IF } xv = xs \text{ AND } i-p = 0 \quad ; \quad XI = xs/2$$

$$\text{IF } xv \neq xs \text{ AND } i+p = 0 \quad ; \quad XI = xs$$

$$\text{IF } xv \neq xs \text{ AND } a=0 \text{ AND } i/xv = p/xs \quad ; \quad XI = xs/2$$

$$\text{IF } xv \neq xs \text{ AND } a \neq 0 \text{ AND } i/xv = p/xs \quad ;$$

$$XI = \cos(i\pi a/xv) \cdot xs/2$$

IF $XV \neq XS$ AND $a=0$ AND $i/XV \neq P/XS$;

$$XI = \sin(\text{ALPHA}) (V1+V2) (-1)^{(P+2)} (1/2)$$

IF $XV \neq XS$ AND $a \neq 0$ AND $i/XV \neq P/XS$;

$$XI = (\sin(\text{GAMMA}) (-1)^{(P+2)} - \sin(i\pi a/XV)) / 2$$

$$\cdot \left((1/\pi) / (i/XV + P/XS) + (1/\pi) / (i/XV - P/XS) \right)$$

WHERE

$$\text{ALPHA} = i\pi XS / XV$$

$$V1 = 1 / (\pi i/XV + \pi P/XS)$$

$$V2 = 1 / (\pi i/XV - \pi P/XS)$$

$$\text{GAMMA} = i\pi XS / XV + i\pi a / XV$$

The solution for YI is analogous.

The subroutine ALIGN matches the structural and acoustic lengths and modal indexes for the analytical solution (see source code).

2. Opening Type 2/Volume Type 2: Circle/Circular Cylinder

This analytic solution assumes the opening is at an end of the circular cylinder.

$$L_{nm} = \frac{1}{A} \int_0^{2\pi} \int_0^a F_n(r, \theta, z') \psi_m(r, \theta, z) r dr d\theta$$

Let

- A - area of opening
- r, θ, z - opening coordinate system
- m - represents two opening indexes; p, q
- n - represents three volume indexes; ijk
- zv - length of the circular cylinder
- z' - constant z location in volume
- a - radius of circle opening

$$F_n(r, \theta, z') = \cos \frac{K\pi z'}{Z_V} \cos j\theta J_j(K_{ji} r)$$

$$\psi_m(r, \theta) = \cos g\theta J_g(K_{gp} r)$$

$$L_{nm} = \frac{1}{A} \cos \frac{K\pi z'}{Z_V} \int_0^a J_j(K_{ji} r) J_g(K_{gp} r) r dr$$

$$\cdot \int_0^{2\pi} \cos j\theta \cos g\theta d\theta$$

with

p, q - opening modal indexes

i, j, k - volume modal indexes

K_{ji} - modal constant for circular cylinder (see volume type 2)

K_{pq} - modal constant for circular opening (see opening type 2)

$$L_{nm} = \frac{1}{A} \cos \frac{K\pi z'}{Z_V} \cdot RI \cdot TI$$

WHERE

$$RI = \int_0^a J_j(K_{ji} r) J_g(K_{gp} r) r dr$$

$$TI = \int_0^{2\pi} \cos j\theta \cos g\theta d\theta$$

$$IF \ j = 8 \ ;$$

$$RI = \frac{a}{(K_{ji}^2 - K_{gp}^2)} \left(K_{gp} J_8(K_{gp} a) J_8'(K_{gp} a) - K_{ji} J_j(K_{ji} a) \cdot J_j'(K_{ji} a) \right)$$

$$IF \ j = 8 \text{ AND } j \neq 0 \ ; \ TI = \pi$$

$$IF \ |j - 8| > 0 \ ; \ TI = 0$$

$$IF \ j = 8 \text{ AND } j = 0 \ ; \ TI = 2\pi$$

3. Opening Type 3/Volume Type 2: Annulus of Concentric Circle/Circular Cylinder

This analytic solution assumes the opening is at an end of the circular cylinder and that the r, θ , and z coordinates of both elements are aligned.

$$L_{nm} = \frac{1}{A} \int_0^{2\pi} \int_a^b F_n(r, \theta, z') \psi_m(r, \theta) r dr d\theta$$

Let

A - area of the opening

r, θ, z - opening coordinate system

m - represents the two opening indexes; p, q corresponding to the r - and θ - directions

n - represents the three volume indexes; i, j, k corresponding to the r -, θ -, and z -directions

z_v - length of circular cylinder

z' - constant z locaton in the volume's coordinate system of the opening

a - inside radius of opening

b - outside radius of opening

$$F_n(r, \theta, z') = \cos\left(\frac{K\pi z'}{z_v}\right) \cos(j\theta) J_j(K_{ji} r)$$

$$\psi_m(r, \theta) = \cos g\theta Q_g(K_{gp} r)$$

$Q_q(x)$ - see opening type 3

K_{ij} - circular cylinder modal constants (see volume type 1)

K_{qp} - annulus of concentric circle modal constants (see opening type 3)

$$L_{nm} = \frac{1}{A} \cos \frac{K\pi z'}{z_v} \cdot RI \cdot TI$$

WHERE

$$RI = \int_a^b J_j(K_{ji} r) Q_g(K_{gp} r) r dr$$

EXPAND ON RI ,

$$RI = \int_a^b J_g(K_{gp} r) J_j(K_{ji} r) r dr \\ - \frac{J_g'(K_{gp} b)}{Y_g'(K_{gp} b)} \int_a^b Y_g(K_{gp} r) J_j(K_{ji} r) r dr$$

AND

$$TI = \int_0^{2\pi} \cos(j\theta) \cos(g\theta) d\theta$$

IF $j = g$ AND $j \neq 0$;

$$RI = VI(b) - VI(a)$$

$$TI = \pi$$

IF $|j - g| > 0$;

$$RI = 1.0$$

$$TI = 0$$

IF $j = g$ AND $j = 0$

$$RI = VI(b) - VI(a)$$

$$TI = 2\pi$$

WHERE

$$VI(r) = \frac{r}{(K_{ji}^2 - K_{gp}^2)} \left(K_{gp} J_j(K_{ji} r) J_j'(K_{gp} r) - K_{ji} J_j(K_{gp} r) J_j'(K_{ji} r) \right) - \frac{J_j'(K_{gp} b)}{J_j'(K_{gp} b)} \frac{r}{(K_{ji}^2 - K_{gp}^2)} \cdot (K_{gp} J_j(K_{ji} r) Y_j'(K_{gp} r) - K_{ji} Y_j(K_{gp} r) J_j'(K_{ji} r))$$

4. Opening Type 3/Volume Type 3: Annulus of Concentric Circle/Annulus of Concentric Circular Cylinder

This analytic solution assumes the opening is at the end of the concentric circular cylinder annulus and that the r, θ , and z coordinates of both elements are aligned.

$$L_{nm} = \frac{1}{A} \int_0^{2\pi} \int_a^b F_n(r, \theta, z') \psi_m(r, \theta) r dr d\theta$$

- Let
- A - area of opening
 - a - inside radius of opening
 - b - outside radius of opening
 - r, θ, z - opening coordinate system
 - m - represents two opening indexes; p, q
 - n - represents three volume indexes; i, j, k
 - z' - constant z location, in the volume's coordinate system, of the opening
 - zv - length of concentric circular cylinder
 - B - outside radius of concentric circular cylinder

$$F_n(r, \theta, z') = \cos \frac{k\pi z'}{z_v} \cos j\theta Q_j(k_{ji} r)$$

$$\psi_m(r, \theta) = \cos g\theta Q_g(k_{gp} r)$$

$Q_j(x)$ - see volume type 3

$Q_q(x)$ - see opening type 3

K_{ij} - concentric circular cylinder modal constant; see volume type 3

K_{qp} - concentric circle modal constants; see opening type 3

$$L_{nm} = \frac{1}{A} \cos \frac{k\pi z'}{z_v} \cdot RI \cdot TI$$

where

$$RI = \int_a^b Q_j(k_{ji} r) Q_g(k_{gp} r) r dr$$

$$TI = \int_0^{2\pi} \cos j\theta \cos g\theta d\theta$$

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EXPANDING ON RI,

$$\begin{aligned}
 RI = & \int_a^b \left\{ J_j(k_{ji} r) J_g(k_{gp} r) - J_j(k_{ji} r) \frac{J_g'(k_{gp} b)}{Y_g'(k_{gp} b)} Y_g(k_{gp} r) \right. \\
 & - J_g(k_{gp} r) \frac{J_j'(k_{ji} B)}{Y_j'(k_{ji} B)} Y_j(k_{ji} r) \\
 & \left. + Y_j(k_{ji} r) Y_g(k_{gp} r) \frac{J_j'(k_{ji} B)}{Y_j'(k_{ji} B)} \frac{J_g'(k_{gp} b)}{Y_g'(k_{gp} b)} \right\} r dr
 \end{aligned}$$

DEFINE

$$\begin{aligned}
 VJ(\alpha, \beta, l, r) &= \int J_l(\alpha r) J_l(\beta r) r dr \\
 &= \frac{r}{(\beta^2 - \alpha^2)} (\alpha J_l(\beta r) J_l'(\alpha r) - \beta J_l(\alpha r) J_l'(\beta r))
 \end{aligned}$$

$$\begin{aligned}
 VY(\alpha, \beta, l, r) &= \int Y_l(\alpha r) Y_l(\beta r) r dr \\
 &= \frac{r}{(\beta^2 - \alpha^2)} (\alpha Y_l(\beta r) Y_l'(\alpha r) - \beta Y_l(\alpha r) Y_l'(\beta r))
 \end{aligned}$$

$$\begin{aligned}
 VJY(\alpha, \beta, l, r) &= \int J_l(\alpha r) Y_l(\beta r) r dr \\
 &= \frac{r}{(\beta^2 - \alpha^2)} (\alpha Y_l(\beta r) J_l'(\alpha r) - \beta J_l(\alpha r) Y_l'(\beta r))
 \end{aligned}$$

IF $j=8$ AND $j \neq 0$;

$$RI = VJ(K_{ji}, K_{8P}, j, b) - VJ(K_{ji}, K_{8P}, j, a)$$

$$- \frac{J'_8(K_{8P}b)}{Y'_8(K_{8P}b)} \left(VJY(K_{ji}, K_{8P}, j, b) - VJY(K_{ji}, K_{8P}, j, a) \right)$$

$$- \frac{J'_j(K_{ji}B)}{Y'_j(K_{ji}B)} \left(VJY(K_{8P}, K_{ji}, j, b) - VJY(K_{8P}, K_{ji}, j, a) \right)$$

$$+ \frac{J'_j(K_{ji}B)}{Y'_j(K_{ji}B)} \frac{J'_8(K_{8P}b)}{Y'_8(K_{8P}b)} \left(VY(K_{ji}, K_{8P}, j, b) - VY(K_{ji}, K_{8P}, j, a) \right)$$

$$TI = \pi$$

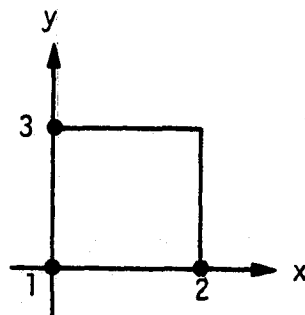
IF $|j-8| > 0$;

$$TI = 0$$

PART IV. STRUCTURAL ELEMENTS: MODAL ANALYSIS

1a. Structure Type 1: Rectangular Shape With Fourier Series Mode Descriptions

1b. Shape



1c. Surface Equations

$Z = 0.0$	-	Surface equation
$G = 1.0$	-	Geometry correction factor
$RJ = 1.0$	-	Jacobian

1d. Natural Frequency Equation and Structural Constants

Natural frequencies provided as data.

1e. Mode Shape

$$\varphi_m(x, y) = \sum_p^{MX} \sum_q^{NY} {}_m B_{pq} \sin \frac{p\pi x}{XL} \sin \frac{q\pi y}{YL}$$

where ${}_m B_{pq}$ - coefficients of Fourier series description of mode m

$XL = \text{SNODC}(2,1,I) = \text{length } x\text{-direction}$

$YL = \text{SNODC}(3,2,I) = \text{length } y\text{-direction}$

No other structural constants are required.

1f. Summary of Program Variables Associated With the Surface Element Description

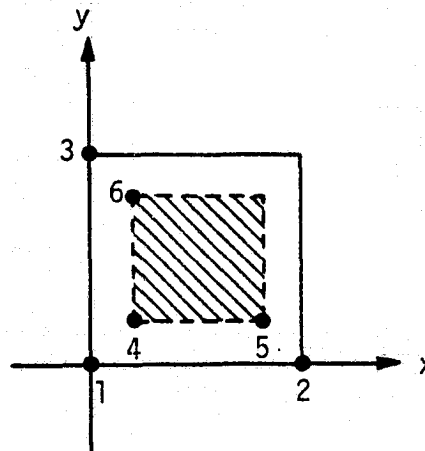
ISUR - assigned surface number
 ISTYP(ISUR) - surface type
 SNODC(MXS,3,NS) - array holding node points in the surface component coordinate system
 WM(1,MWM,ISUR) - natural frequency of mode MWM
 WM(2,MWM,ISUR) - modal index p of mode MWM
 WM(3,MWM,ISUR) - modal index q of mode MWM
 SC(NSC,ISUR) - structural constants for modal analysis
 G(x,y) = geometry correction factor

$$= \left(1 + \left(\frac{\partial z}{\partial x} \right)^2 + \left(\frac{\partial z}{\partial y} \right)^2 \right)^{1/2}$$

where $z = f(x,y)$ equation of the surface.

2a. Structural Type 2: Flat, Orthotropic, Rectangular Panel With Simply Supported Edges

2b. Shape



where the area of integration is indicated by the nodes 4, 5, and 6.

2c. Surface Equations

Z = 0.0: surface equation

G = 1.0: geometry correction factor

AJ = 1.0: Jacobian

2d. Natural Frequency Equation and Structural Constants

$$\omega_{pq}^2 = \frac{D}{m} \left[\left(\sqrt{\frac{D_x}{D}} \left(\frac{p}{xL} \right)^2 + \sqrt{\frac{D_y}{D}} \left(\frac{q}{yL} \right)^2 \right)^2 + 2 \left(\frac{p}{xL} \right)^2 \left(\frac{q}{yL} \right)^2 \left(\frac{D_{xy}}{D} - 1 \right) \right]$$

D_x - bending rigidity of structure in section perpendicular to the x-axis

D_y - bending rigidity of structure in section perpendicular to the y-axis

$D_{xy} = (D_x \nu_x + D_y \nu_y + 4Gh^3/12) / 2$

$D = D_x D_y$

ν_x - Poisson's ratio for x-direction

ν_y - Poisson's ratio for y-direction

G - material's shear modulus

h - panel's thickness

m - mass per unit surface area

p, q - modal indexes

xL, yL - length of panel in the x- and y-directions respectively

Note that if the panel is isotropic, the natural frequency equation reduces to

$$\omega_{pq}^2 = \frac{D}{m} \left(\left(\frac{p}{xL} \right)^2 + \left(\frac{q}{yL} \right)^2 \right)^2$$

Assign D_x - SC(1,IS)
 D_y - SC(2,IS)
 $4Gh^3/12$ - SC(3,IS)
 γ_x - SC(4,IS)
 γ_y - SC(5,IS)
 m - SC(6,IS)

2e. Mode Shape Equations

$$\psi_{p,q}(x,y) = \sin \frac{p\pi x}{x_L} \sin \frac{q\pi y}{y_L} / D_{p,q}$$

$$D_{p,q} = \left(\frac{\rho h A}{4} \right)^{1/2} \text{ FOR } p, q \geq 1$$

The selection of D_{mn} as shown yields the generalized mass:

$$M_{p,q} = \rho h \int_A \psi_{p,q}^2(x,y) dA = 1.0$$

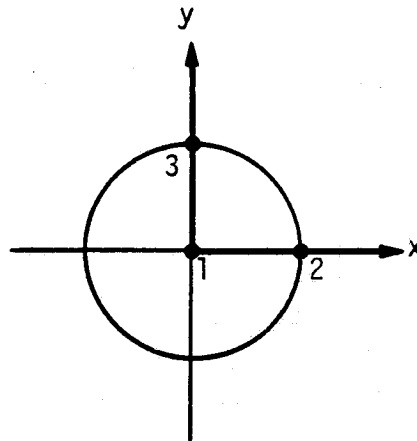
FOR $p, q \geq 1$

2f. Summary of Program Variables Associated With the Surface Element Description

See section f of surface type 1.

3a. Structural Type 3: Circular Shape With Fourier Series Mode Description

3b. Shape



3c. Surface Equations

- $Z = 0.0$ - Surface equation
 $G = 1.0$ - Geometry correction factor
 $AJ = 1.0$ - Jacobian

3d. Natural Frequency Equation and Structural Constants

Natural frequencies provided as data along with Fourier series data.

3e. Mode Shape

$$\psi_m(x, y) = \sum_p^{m_x} \sum_q^{n_x} B_{pq} \sin \frac{p\pi x}{xL} \sin \frac{q\pi y}{yL}$$

where B_{pq} - coefficients of Fourier series description of mode m

$$xL = 2 * SNODC(2,1,I)$$

$$yL = xL$$

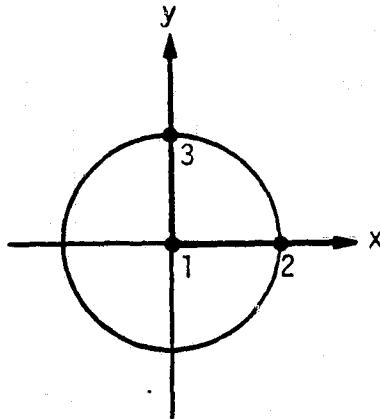
Since no additional structural constants are needed, NSC = 0.

3f. Summary of Program Variables Associated With the Surface Element Description

See section f of surface type 1.

4a. Structural Type 4: Thin, Homogeneous, Circular Panel

4b. Shape



4c. Surface Equations (Cylindrical Coordinate System r, θ, z)

- $Z = 0.0$ - Surface equation
- $G = 1.0$ - Geometry correction factor
- $AJ = r$ - Jacobian

4d. Natural Frequency Equation and Structural Constants

$$\omega_{pg} = \frac{h}{4a} \sqrt{\frac{E}{3\rho(1-\nu^2)}} \cdot \left(\frac{K_{gp} a}{\pi} \right)^2$$

where

- h - thickness
- a - radius
- ρ - density
- E - modulus of elasticity
- ν - Poisson's constant
- p, q - modal indexes in the r - and θ -directions respectively
- K_{gp} - the roots of the equation : (SEE NEXT PAGE)

$$I_8(K_{8P}a) J_8'(K_{8P}a) = J_8(K_{8P}a) I_8'(K_{8P}a)$$

Assign,

$$SC(1, I) = h/4a \sqrt{E/3\rho(1-\nu^2)}$$

$$SC(2, I) = \rho h$$

4e. Mode Shape Equation

$$\psi_{p8}(r, \theta) = \frac{\sin(8\theta)}{D_{p8}} \left(J_8(K_{8P}r) + \frac{J_8(K_{8P}a)}{I_8(K_{8P}a)} I_8(K_{8P}r) \right)$$

$J_m(x)$ - Bessel function of the first kind

$I_m(x)$ - hyperbolic Bessel function of the first kind = $i^{-m}(j_m(ix))$

$$D_{p8} = \left[\rho h \int_0^{2\pi} \int_0^a \psi_{p8}^2(r, \theta) r dr d\theta \right]^{1/2}$$

$$= \rho h A \left(\frac{\mathcal{E}_2}{2} \right) \left\{ (J_8'(K_{8P}a))^2 + \left(1 - \frac{8^2}{K_{8P}^2 a^2} \right) J_8^2(K_{8P}a) \right\}$$

$$+ 2 \frac{J_8(K_{8P}a)}{I_8(K_{8P}a)} \left(J_8^2(K_{8P}a) + \left(1 - \frac{8^2}{K_{8P}^2 a^2} \right) I_8^2(K_{8P}a) \right)$$

$$+ \left(\frac{J_8(K_{8P}a)}{I_8(K_{8P}a)} \right)^2 \left(I_8'^2(K_{8P}a) + \left(1 - \frac{8^2}{K_{8P}^2 a^2} \right) I_8^2(K_{8P}a) \right) \left\} \right]^{1/2}$$

HENCE,

$$M_{p8} = \rho h \int_A \psi_{p8}^2(r, \theta) dA = 1.0$$

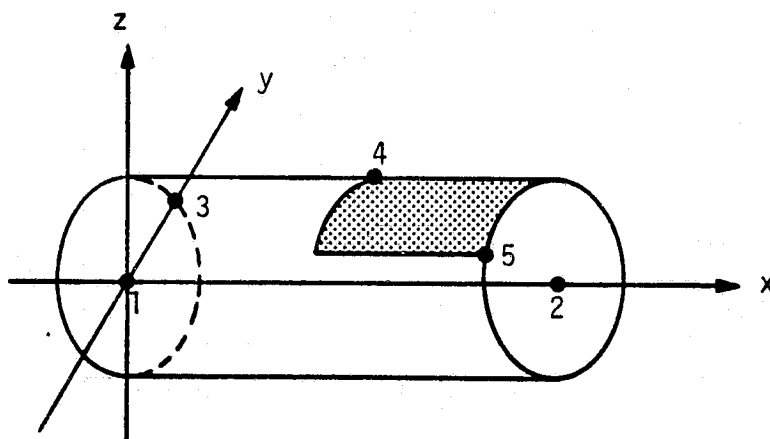
4f. Summary of Program Variables Associated With the Structural Element Description

See part f of structural element 1.

5a. Structural Type 5: Frame-Stiffened Orthotropic Whole Shell

The frame-stiffened orthotropic whole shell has shear diaphragm end conditions.

5b. Shape



Since the whole shell is not single valued in the z-coordinate direction, the shell must be partitioned into subsurfaces that are single valued in the z-direction. Nodes 4 and 5 are used to define the location of the subsurfaces as shown.

5c. Surface Equations (Cylindrical Coordinate System r, θ, x)

$r = \text{constant}$	-	Surface equation
$G = 1.0$	-	Geometry correction factor
$AJ = r$	-	Jacobian

5d. Natural Frequency Equation

The natural frequency must be determined by the lowest frequency solution of the shell matrix equation $[Z'] = 0$, where

$$[Z'] = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

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AND

$$a_{11} = \frac{C_{11}}{C_{22}} \left(\frac{\rho \pi b}{xL} \right)^2 + \frac{C_{11}}{C_{22}} \frac{(1-\nu)}{2} \left(\frac{\delta}{2} \right)^2 + \frac{\rho_s b^2 \omega^2}{C_{22}}$$

$$a_{22} = \frac{(1-\nu)}{2} \frac{C_{11}}{C_{22}} \left(\frac{\rho \pi b}{xL} \right)^2 + \left(\frac{\delta}{2} \right)^2 + \frac{\rho_s b^2 \omega^2}{C_{22}}$$

$$a_{33} = 1 + \frac{D_{22}}{b^2 C_{22}} \left[\frac{D_{11}}{D_{22}} \left(\frac{\rho \pi b}{xL} \right)^4 + \frac{2 D_{11}}{D_{22}} \left(\frac{\rho \pi b}{xL} \right)^2 \left(\frac{\delta}{2} \right)^2 + \left(\frac{\delta}{2} \right)^4 \right] + \frac{\rho_s b^2 \omega^2}{C_{22}}$$

$$a_{21} = a_{12} = \frac{(1+\nu)}{2} \frac{C_{11}}{C_{22}} \left(\frac{\rho \pi b}{xL} \right) \left(\frac{\delta}{2} \right)$$

$$a_{13} = a_{31} = \nu \frac{C_{11}}{C_{22}} \left(\frac{\rho \pi b}{xL} \right)$$

$$a_{23} = a_{32} = \frac{\delta}{2}$$

and

- p - axial modal index
- q - circumferential modal index
- ρ_s - density of the skin material
- b - radius of the cylinder
- xL - length of the cylinder
- ν - Poisson's constant for cylinder material

AND WHERE

$$C_{11} = E_{S_s} \frac{A_{S_s}}{L_\theta (1-\nu^2)} ; D_{11} = \frac{E_{S_s} I_{S_s}}{L_\theta (1-\nu^2)}$$

$$C_{22} = E_{S_\theta} \frac{A_{S_\theta}}{L_F (1-\nu^2)} + E_F \frac{A_F}{L_F} ; D_{22} = \frac{E_{S_\theta} E_{S_\theta}}{L_F (1-\nu^2)} + \frac{E_F I_{F_\theta}}{L_F}$$

- where
- A_{S_s} - cross-sectional area of load-bearing skin normal to axial direction.
 - A_{S_θ} - effective cross-sectional area of load-bearing skin normal to circumferential direction
 - A_F - frame cross-sectional area
 - I_{S_s} - moment of inertia of skin section normal to axial direction about skin-frame centroid
 - I_{S_θ} - moment of inertia of skin section normal to circumferential direction about skin-frame centroid
 - I_{F_θ} - moment of inertia of frame cross section about skin-frame centroid
 - L_F - axial repeat length of frames
 - L_θ - circumferential length of skin
 - E_{S_s} - axial elasticity of the skin
 - E_{S_θ} - circumferential elasticity of the skin
 - E_F - elasticity of the frame

Assign the following structural constants (NSC=6)

$$SC(1,I) = C_{11}$$

$$SC(2,I) = C_{22}$$

$$SC(3,I) = D_{11}$$

$$SC(4,I) = D_{22}$$

$$SC(5,I) = \nu$$

$$SC(6,I) = \rho_s$$

5e. Mode Shape Equation in Cylindrical Coordinates (r, , z)

$$r = \text{constant (SNODC(3,2,ISUR))}$$

$$\psi_{pg}(x, \theta) = \sin\left(\frac{p\pi x}{x_L}\right) \cos(q\theta) / D_{pg}$$

WHERE

$$D_{pg} = \rho h \int_0^{2\pi} \int_0^{x_L} \sin^2\left(\frac{p\pi x}{x_L}\right) \cos^2(q\theta) dx d\theta$$

$$= \left(\rho h A \frac{\epsilon_p \epsilon_q}{4}\right)^{1/2}$$

where

A = area of shell segment

$$\epsilon_p = 1 \text{ if } p \neq 0$$

$$= 2 \text{ if } p = 0$$

$$\epsilon_q = 1 \text{ if } q \neq 0$$

$$= 2 \text{ if } q = 0$$

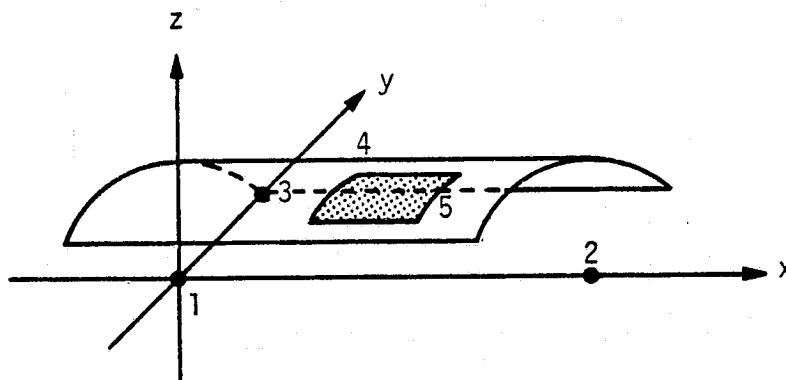
THIS RESULTS IN

$$M_{pg} = \rho h \int_A \psi_{pg}^2(x, \theta) dA = 1.0$$

6a. **Structural Type 6: Frame-Stiffened Orthotropic Shell Segment**

This structure type describes the motion of a frame-stiffened orthotropic shell segment with shear diaphragm end conditions at the boundaries.

6b. **Shape**



6c. **Surface Equations** (Cylindrical Coordinates (r, θ, x))

$r = \text{constant}$	-	Surface equation
$G = 1.0$	-	Geometry correction factor
$AJ = r$	-	Jacobian

6d. **Natural Frequency Equation**

The natural frequency must be determined by the lowest frequency solution of the shell matrix equation $[\mathcal{L}'] = 0$, where

$$[\mathcal{L}'] = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

AND

$$a_{11} = \frac{C_{11}}{C_{22}} \left(\frac{\rho \pi b}{xL} \right)^2 + \frac{C_{11}}{C_{22}} \frac{(1-\nu)}{2} \left(\frac{8\pi}{\alpha} \right)^2 + \frac{\rho_s b^2}{C_{22}} \omega^2$$

$$a_{22} = \frac{(1-\nu)}{2} \frac{C_{11}}{C_{22}} \left(\frac{\rho \pi b}{xL} \right)^2 + \left(\frac{8\pi}{\alpha} \right)^2 + \frac{\rho_s b^2}{C_{22}} \omega^2$$

$$a_{33} = 1 + \frac{D_{22}}{b^2 C_{22}} \left[\frac{D_{11}}{D_{22}} \left(\frac{\rho \pi b}{xL} \right)^4 + 2 \frac{D_{11}}{D_{22}} \left(\frac{\rho \pi b}{xL} \right)^2 \left(\frac{8\pi}{\alpha} \right)^2 + \left(\frac{8\pi}{\alpha} \right)^4 \right] + \frac{\rho_s b^2}{C_{22}} \omega^2$$

$$a_{21} = a_{12} = \frac{(1+\nu)}{2} \frac{C_{11}}{C_{22}} \left(\frac{\rho \pi b}{xL} \right) \left(\frac{8\pi}{\alpha} \right)$$

$$a_{13} = a_{31} = \nu \frac{C_{11}}{C_{22}} \left(\frac{\rho \pi b}{xL} \right)$$

$$a_{23} = a_{32} = \left(\frac{8\pi}{\alpha} \right)$$

and

α - angular length of shell segment in radians

p - axial modal index

q - circumferential modal index

ρ_s - density of the skin material

b - radius of the cylinder

xL - length of the cylinder

ν - Poisson's constant for cylinder material

AND WHERE

$$C_{11} = E_{S_s} \frac{A_{S_s}}{L_\theta (1-\nu^2)} \quad ; \quad D_{11} = \frac{E_{S_s} I_{S_s}}{L_\theta (1-\nu^2)}$$

$$C_{22} = E_{S_\theta} \frac{A_{S_\theta}}{L_F (1-\nu^2)} + E_F \frac{A_F}{L_F} \quad ; \quad D_{22} = \frac{E_{S_\theta} E_{S_\theta}}{L_F (1-\nu^2)} + \frac{E_F I_{F_\theta}}{L_F}$$

- where
- A_{S_s} - cross-sectional area of load-bearing skin normal to axial direction.
 - A_{S_θ} - effective cross-sectional area of load-bearing skin normal to circumferential direction
 - A_F - frame cross-sectional area
 - I_{S_s} - moment of inertia of skin section normal to axial direction about skin-frame centroid
 - I_{S_θ} - moment of inertia of skin section normal to circumferential direction about skin-frame centroid
 - I_{F_θ} - moment of inertia of frame cross section about skin-frame centroid
 - L_F - axial repeat length of frames
 - L_θ - circumferential length of skin
 - E_{S_s} - axial elasticity of the skin
 - E_{S_θ} - circumferential elasticity of the skin
 - E_F - elasticity of the frame

Assign the following structural constants

$$SC(1,I) = C_{11}$$

$$SC(2,I) = C_{22}$$

$$SC(3,I) = D_{11}$$

$$SC(4,I) = D_{22}$$

$$SC(5,I) = \nu$$

6e. Mode Shape Equation

$r = \text{constant}$

$$\psi_{p,q}(x,\theta) = \sin\left(\frac{p\pi x}{x_L}\right) \sin\left(\frac{q\pi\theta}{\alpha}\right) / D_{p,q}$$

WHERE

$$\begin{aligned} D_{p,q} &= eh \int_0^\alpha \int_0^{x_L} \sin^2\left(\frac{p\pi x}{x_L}\right) \sin^2\left(\frac{q\pi\theta}{\alpha}\right) dx d\theta \\ &= (eh A \epsilon_p \epsilon_q / 4)^{1/2} \end{aligned}$$

where

$A = \text{area of shell segment}$

$$\epsilon_p = 1.0 \text{ if } p \neq 0$$

$$= 2.0 \text{ if } p = 0$$

$$\epsilon_q = 1.0 \text{ if } q \neq 0$$

$$= 2.0 \text{ if } q = 0$$

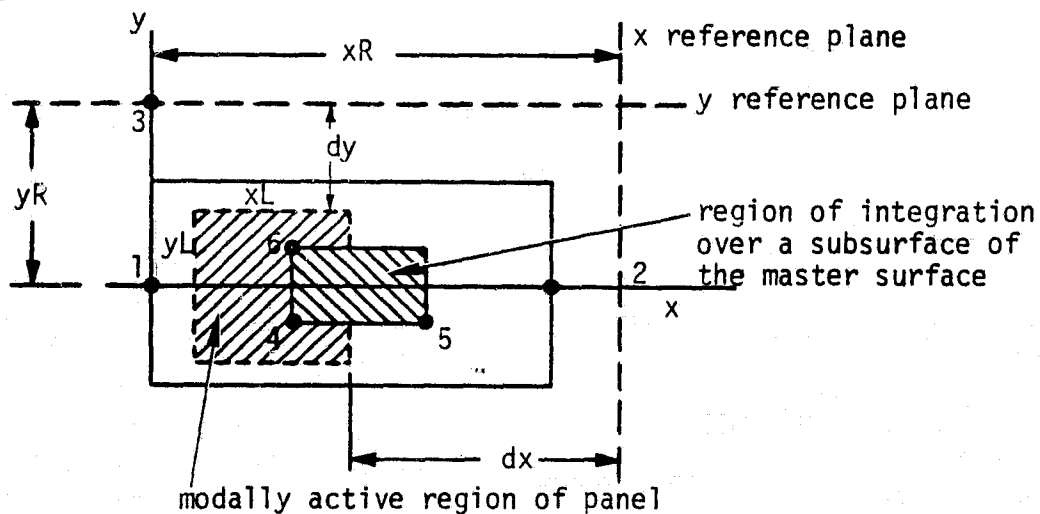
HENCE

$$M_{p,q} = eh \int_A \psi_{p,q}^2(x,\theta) dA = 1.0$$

7a. Structural Type 7: Rectangular Panel With Sine Series Mode Shape Over Specified Modally Active Regions of the Panel

This particular surface was added to allow approximate modeling of a surface's modal motion by dividing the surface into modally active regions for each mode. The method was developed by a NASA contractor to approximate finite element determined mode shapes of the Space Shuttle payload bay structures. (Pope, L. D., et al. Space Shuttle Payload Bay Acoustics Prediction Study: Volume II, Analytical Model. NASA CR 159956, March 1980.)

7b. Shape



dx - distance from x reference plane to modally active region

dy - distance from y reference plane to modally active region

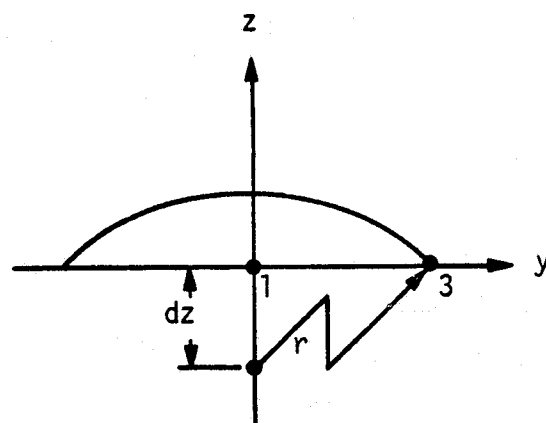
xL - x length of modally active region

yL - y length of modally active region

xR, yR - length from panel origin to the reference planes

The above listed parameters are placed in storage for each mode of the surface. Those areas of the surface that are outside the modally active region are assumed to have zero modal deflection. Recall that the modally active region may change from mode to mode. The surface may also be curved in the z-direction as illustrated below.

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where r is the radius of curvature (given as a structural constant) and dz is the offset of the circle center from the y -axis as indicated.

7c. Surface Equations

Flat: $Z = 0.0$ - Surface equation

$G = 1.0$ - Geometry correction factor

$AJ = 1.0$ - Jacobian

Curved: $Z = (r^2 - y^2)^{1/2} - DZ$

$G = (1 + y^2/(r^2 - y^2))^{1/2}$

$AJ = 1.0$

$DZ = (r^2 - \text{SNODC}(3, 2, IS)^2)^{1/2}$

7d. Natural Frequencies

The natural frequencies of this surface are given as data.

7e. Mode Shapes

Translate the coordinates of integration x, y into the coordinates of the modally active region.

$x_C = x - (x_R - dx - x_L)$: both flat and curved surfaces

$y_C = y - (y_R - dy - y_L)$: flat surface

$= (r \cos^{-1}(\text{SNODC}(3, 2, IS)/r) + dy + y_R) - r \cos(y/r)$: curved surface

where x_L, y_L - length of the modally active region in the x- and y-direction respectively

x_R, y_R - reference point for x- and y-directions respectively

dx, dy - distance from reference planes to the modally active regions

$$\psi_{pq}(x,y) = \sin(p\pi x/x_L) \sin(q\pi y/y_L) / a_{pq}$$

a_{pq} - combined mode shape normalization and amplitude factor such that

$$m_{pq} = \rho h \int_A \psi_{pq}^2(x,y) dA = 1.0$$

x_L, y_L, dx, dy , and a_{pq} may change for each mode of the structure. If x or y should fall outside the modally active region for the mode, then $\psi_{pq}(x, y)$ is set to zero. Also, y is the length along the surface of a curved door.

7f. Summary of Program Variables Associated With the Surface Element Description

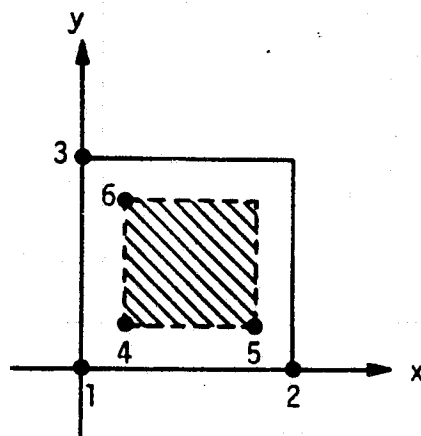
- ISUR - assigned surface number
- ISTYP(ISUR) - surface type
- SNODC(MXS,3,NS) - array holding node points in the surface component coordinate system
- WM(1,MWM) - natural frequency of mode MWM
- WM(2,MWM) - modal index p of mode MWM
- WM(3,MWM) - modal index q of mode MWM
- SC(NSC,ISUR) - structural constants for modal analysis
 - SC(1,ISUR) - number of modes with BPQ type data
 - SC(2,ISUR) - radius of surface curvature (-1.0 if flat)
- BPQ(MX,NX,NSMX) - the factors for the calculation of the node shape are read into this array in the routine DATALD under section n. Structural constants.
- BPQ(1,1,MWM) - frequency
- BPQ(1,2,MWM) - p modal index placed directly into array WM
- BPQ(1,3,MWM) - q modal index

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- BPQ(1,4,MWM) - normalizing factor
- BPQ(1,5,MWM) - amplitude factor
- BPQ(1,6,MWM) - x-modally active dimension (xL)
- BPQ(1,7,MWM) - y-modally active dimension (yL)
- BPQ(1,8,MWM) - x-distance to x reference plane (dx)
- BPQ(1,9,MWM) - y-distance to y reference plane (dy)

8a. Structural Type 8: Flat, Orthotropic, Rectangular Panel With Clamped Edges

8b. Shape



The area of integration is indicated by the nodes 4, 5, and 6.

8c. Surface Equations

- Z = 0.0 - surface equation
- G = 1.0 - geometry correction factor
- AJ = 1.0 - Jacobian

8d. Natural Frequency Equation and Structural Constants

$$\omega_{pg} = \frac{\pi^2}{m^{1/2}} \left[\frac{G_1^4 D_x}{a^4} + \frac{G_2^4 D_y}{b^4} + \frac{2H_1 H_2 D_{xy}}{a^2 b^2} \right]^{1/2}$$

where

$$D_x = \frac{E_x h^3}{12(1 - \nu_x \nu_y)}$$

$$D_y = \frac{E_y h^3}{12(1 - \nu_x \nu_y)}$$

$$D_k = \frac{Gh^3}{12}$$

$$D_{xy} = D_x \nu_y + 2 D_k$$

and

E_x, E_y - modulus of elasticity of panel in x and y directions respectively

ν_x, ν_y - poisson's ratio in the x and y directions respectively

G - Shear modulus

h - thickness of panel

m - material mass per unit surface area

a, b - length of panel in x and y directions respectively

The coefficients of the natural frequency approximation are

$$G_1 = 1.506 ; p=1 \text{ AND } (p + 1/2) ; p > 1$$

$$G_2 = 1.506 ; g=1 \text{ AND } (g + 1/2) ; g > 1$$

$$H_1 = 1.248 ; p=1 \text{ AND } G_1^2 \left(1 - \frac{2}{\pi G_1}\right) ; p > 1$$

$$H_2 = 1.248 ; g=1 \text{ AND } G_2^2 \left(1 - \frac{2}{\pi G_2}\right) ; g > 1$$

Assign

$$SC(1,IS) = Dx$$

$$SC(2,IS) = Dy$$

$$SC(3,IS) = Dk$$

$$SC(4,IS) = \bar{v}_x$$

$$SC(5,IS) = \bar{v}_y$$

$$SC(6,IS) = m$$

8e. Mode Shape Equations

$$\psi_{pq}(x,y) = (A_p (\cosh(\pi(p+1/2)\bar{x}) - \cos(\pi(p+1/2)\bar{x}) - \sigma_p (\sinh(\pi(p+1/2)\bar{x}) - \sin(\pi(p+1/2)\bar{x})))$$

$$\bullet A_q (\cosh(\pi(q+1/2)\bar{y}) - \cos(\pi(q+1/2)\bar{y}) - \sigma_q (\sinh(\pi(q+1/2)\bar{y}) - \sin(\pi(q+1/2)\bar{y})))) \\ / (D_p m_T D_q m_T)$$

where M_T = square root of the total panel mass and

n^*	A_n	σ_n	D_n
1	0.630	0.982	.396
2	0.663	1.001	.439
≥ 3	0.661	1.00	.437

*n is the p or q index.

AND $\bar{x} = x/a$
 $\bar{y} = y/b$

The mode shape is normalized such that

$$M_{p8} = \rho h \int_A \psi_{p8}^2(x,y) dA = 1.0$$

8f. Summary of Program Variables Associated With the Structural Element Description

See section f of structure type 1.

APPENDIX B

PROGRAM LIBRARY OF SEA DESCRIPTIONS

1a. SEA DESCRIPTION 1: EQUIVALENT ORTHOTROPIC RECTANGULAR PANEL

Since experiments have shown the joint acceptance to vary little with end conditions, this description is valid for all equivalent panels with simply supported to fixed boundaries.

1b. MODAL DENSITY EQUATIONS

The modal density and average modal indexes for each band of interest are calculated by evaluating the equation

$$\omega_{mn}^2 = \pi^4 \frac{D}{\rho h} \left[\left(\sqrt{\frac{D_x}{D}} \left(\frac{m}{x_L} \right)^2 + \sqrt{\frac{D_y}{D}} \left(\frac{n}{y_L} \right)^2 \right)^2 + 2 \left(\frac{m}{x_L} \right)^2 \left(\frac{n}{y_L} \right)^2 \left(\frac{D_{xy}}{D} - 1 \right) \right]$$

where

D_x - bending rigidity of structure in section perpendicular to the x-axis

D_y - bending rigidity of structure in section perpendicular to the y-axis

$D_{xy} = (D_x x + D_y y + 4Gh^3/12)^2$

$D = D_x D_y$

ν_x - Poisson's ratio for x-direction

ν_y - Poisson's ratio for y-direction

G - material's shear modulus

h - panel thickness

ρ - density of panel material

m, n - modal indexes

XL, YL - length of panel in the x- and y-directions, respectively.

Note that if the panel is isotropic, the natural frequency equation reduces to

$$\omega_{mn}^2 = \pi^4 \frac{D}{\rho h} \left(\left(\frac{m}{XL} \right)^2 + \left(\frac{n}{YL} \right)^2 \right)^2$$

Assign (see also section 1d)

D_x - WMH(1,1)

D_y - WMH(1,2)

$4Gh^3/12$ - WMH(1,3)

x - WMH(1,4)

y - WMH(1,5)

h - WMH(1,6)

XL - WMH(1,7)

YL - WMH(1,8)

An iterative procedure is used to calculate the number of modes in each band from the equation and to calculate the average value of the modal indexes in each band.

1c. TYPICAL JOINT ACCEPTANCE DEFINITION

The joint acceptance must be calculated for each random pressure field type held in the program library, if possible.

- o For the reverberant pressure field (pressure field type 1),

$$J_m^2(\omega) = \frac{1}{A^2} \int_x \int_y \int_{x'} \int_{y'} \frac{\sin(k(x-x'))}{k(x-x')} \frac{\sin(k(y-y'))}{k(y-y')}$$

$$\cdot \sin\left(\frac{m\pi x}{x_L}\right) \sin\left(\frac{m\pi x'}{x_L}\right) \sin\left(\frac{n\pi y}{y_L}\right) \sin\left(\frac{n\pi y'}{y_L}\right)$$

$$\cdot dy' dx' dy dx$$

where A - area of surface

$$k = \omega / C_0$$

The analytical relation is

$$J_m^2(\omega) = VI(m, x_L, \omega) \cdot VI(n, y_L, \omega)$$

with

$$\begin{aligned} VI(j, l, \omega) = & \frac{1}{2j\pi^2\beta} \left(\cos(\pi(\beta+j)) - \cos(\pi(\beta-j)) \right) \\ & + \frac{1}{2\pi\beta} \left(\sin(\pi(\beta+j)) + \sin(\pi(\beta-j)) \right) \\ & + \frac{1}{\pi^2(j^2 - \beta^2)} \left(1 - (-1)^j \cos(\pi\beta) \right) \end{aligned}$$

and

$$\text{Ci}(z) = \int_0^z \frac{1 - \cos x}{x} dx$$

$$\text{Si}(z) = \int_0^z \frac{\sin x}{x} dx$$

$$\beta = l\omega / c_0 \pi$$

o For the aerodynamic turbulence (pressure field type 2),

$$J_m^2(\omega) = \frac{1}{A^2} \iiint \int \exp[-\alpha_x K_x |x-x'|] \cos(K_x(x-x'))$$

$$\cdot \exp[-\alpha_y K_y |y-y'|] \cos(K_y(y-y'))$$

$$\cdot \sin\left(\frac{m\pi x}{x_L}\right) \sin\left(\frac{m\pi x'}{x_L}\right) \sin\left(\frac{n\pi y}{y_L}\right) \sin\left(\frac{n\pi y'}{y_L}\right)$$

$$\cdot dy' dx' dy dx$$

The analytical solution is

$$J_m^2(\omega) = \frac{1}{A^2} \cdot VI(m, x_L, \alpha_x, K_x) \cdot VI(n, y_L, \alpha_y, K_y)$$

WHERE

$$VI(j, l, \alpha, k) = A(j) (1 - (-1)^j \exp[-\pi \alpha \beta] \cos \pi \beta) \\ + B(j) (-1)^j \exp[-\pi \alpha \beta] \sin \pi \beta \\ + C(j)$$

where

WITH

$$A(j) = \frac{2}{(j\pi)^2 D^2(j)} \left(\left((\alpha^2 - 1) (B/j)^2 + 1 \right)^2 - 4(\alpha (B/j)^2)^2 \right)$$

$$B(j) = \frac{8}{(j\pi)^2 D^2(j)} \alpha (B/j)^2 \left((\alpha^2 - 1) (B/j)^2 + 1 \right)$$

$$C(j) = \frac{1}{(j\pi)^2 D(j)} \alpha (B/j) \left((\alpha^2 + 1) (B/j)^2 + 1 \right)$$

$$D(j) = \left((\alpha^2 + 1) (B/j)^2 + 1 \right)^2 - 4(B/j)^2$$

$$B = \omega l / \pi c_0$$

- o For a random amplitude plane wave field (pressure field type 3),

$$J_m^2(\omega) = \frac{1}{A^2} \int_x \int_y \int_{x'} \int_{y'} \cos \left[\frac{\omega}{c_0} \cos(\theta) (x-x') \right] \\ \cdot \left[\delta(\omega-\omega') + \delta(\omega+\omega') \right] \cdot \cos \left[\frac{\omega}{c_0} \cos(\theta) (y-y') \right] \\ \cdot \left[\delta(\omega-\omega') + \delta(\omega+\omega') \right] \cdot \sin \left(\frac{m\pi x}{x_L} \right) \sin \left(\frac{m\pi x'}{x_L} \right) \\ \cdot \sin \left(\frac{n\pi y}{y_L} \right) \sin \left(\frac{n\pi y'}{y_L} \right) dy' dx' dy dx$$

The analytical solution is

$$J_m^2(\omega) = \frac{1}{A^2} VI(m, x_L, \omega, \theta) VI(n, y_L, \omega, \theta)$$

where

$$VI(s, l, \omega, \theta) = \frac{2}{\pi^2} j^2 (1 - (-1)^j \cos \pi \theta) / (j^2 - \theta^2)^2$$

AND

$$\theta = \frac{\omega l}{c_0 \pi} \cos(\theta)$$

1d. **SUMMARY OF PROGRAM VARIABLES ASSOCIATED WITH THE SEA DESCRIPTION**

WMH(NSEAC, NTOB) - Array of SEA constants that may be allowed to vary with frequency

MD(NMS, NTOB) - Array of modal densities for each band of each master surface

All SEA constants that do not vary with frequency may be backed into the first row of the two-dimensional WMH array.

WMH(1,1) - D_x

WMH(1,2) - D_y

WMH(1,3) - $4Gh^3/12$

WMH(1,4) - $\sqrt{\gamma_x}$

WMH(1,5) - $\sqrt{\gamma_y}$

WMH(1,6) - h

WMH(1,7) - XL

WMH(1,8) - YL

WMH(2, NOB) - m , average m modal index over band

WMH(3, NOB) - n , average n modal index over band

For SEA description type 1: NSEAC = 3.

2a. **SEA DESCRIPTION 2: EQUIVALENT ORTHOTROPIC WHOLE SHELL**

The joint acceptance of a whole equivalent shell with shear diaphragm end conditions is given here in semiempirical form and applies to a reverberant excitation field only.

2b. **MODAL DENSITY EQUATIONS**

$$\begin{aligned} \eta_r &= F1 \cdot 0.178 \sqrt{\omega a / c_L} \cdot D\omega ; \frac{\omega a}{c_L} < 0.9 \\ &= F1 \cdot 0.8 D\omega ; 0.9 < \frac{\omega a}{c_L} < 1.10 \\ &= F1 \cdot 0.25 D\omega ; \frac{\omega a}{c_L} > 1.10 \end{aligned}$$

where $F1 - 2 \cdot \sqrt{3} \ell / t$

ℓ - length of cylinder

t - thickness of cylinder

C_L - longitudinal wave speed in cylinder

a - radius of cylinder

$\Delta\omega$ - bandwidth of interest normalized to the ring frequency

ω - frequency, rad/sec

2c. TYPICAL JOINT ACCEPTANCE DEFINITIONS

For a reverberant pressure field (pressure field type 1),

$$J_m^2(\omega) = (2/3) (4\pi a / (4\pi a + 2\ell)) J_m^2(\omega)_{\text{PLATE}}$$

WHERE $J_m^2(\omega)_{\text{PLATE}}$ IS AS IN SEA DESCRIPTION 1

$$\begin{aligned} \text{WITH } X_L &= \ell \\ Y_L &= 2\pi a \end{aligned}$$

where a - radius of cylinder

ℓ - length of cylinder

A - surface area of cylinder

ω_{cr} - critical frequency of cylinder

$k = \omega / C_0$

C_0 - speed of sound in air

ρ - density of air

ρ_{cyl} - density of cylinder

$$M_r = \rho_{cyl} \cdot t \cdot A$$

2d. SUMMARY OF PROGRAM VARIABLES ASSOCIATED WITH SEA DESCRIPTION

WMH(NSEAC, NTOB) - Array of the SEA factors as a function of band center frequency

WMH(1,1) - a

WMH(1,2) - Q

WMH(1,3) - t

WMH(1,4) - $\rho_{cyl} \lambda$

WMH(1,5) - longitudinal wave speed in cylinder

MD(IS, NOB) - Array of modal densities

For SEA description type 2, therefore, NSEAC = 1.

3a. SEA DESCRIPTION 3: DIRECT DATA

The joint acceptance and modal densities are known from some other source as data.

3b. MODAL DENSITY EQUATIONS

Modal density given directly as data for each band of interest.

3c. TYPICAL JOINT ACCEPTANCE DEFINITIONS

Joint acceptance definitions are also given as data in the order described in section 3d.

3d. SUMMARY OF PROGRAM VARIABLES ASSOCIATED WITH SEA DESCRIPTIONS

WMH(NSEAC, NTOB) - Array of the SEA factors as a function of band center frequency.

WMH(1, NOB) - $RJA(NO B) = J_r^2(\omega_c)$

WMH(2, NOB) - $RJARV(NO B) = J_r^2(\omega_c)^{rev}$

WMH(3, NOB) - modal density in modes/radians/second

For this surface type, NSEAC = 3.

APPENDIX C

PROGRAM LIBRARY OF EXTERNAL PRESSURE FIELDS

1a. PRESSURE FIELD TYPE 1: REVERBERANT PRESSURE FIELD

1b. SURFACE PRESSURE CORRELATION EQUATIONS

$$C(x-x', y-y', \omega) = C_x(x-x', \omega) C_y(y-y', \omega)$$

$$C_x(x-x', \omega) = \frac{\sin(K(x-x'))}{K(x-x')}$$

$$C_y(y-y', \omega) = \frac{\sin(K(y-y'))}{K(y-y')}$$

where the x- and y-directions are assumed separable and

$$K = \omega/c$$

C = speed of sound in the fluid medium

No additional constants need be assigned, so NPFC = 0 for this pressure field type.

1c. GENERALIZED FORCE CALCULATIONS

If the mode shape is given by equation, the joint acceptance is generally numerically calculated. If the mode shape is given by Fourier series, the joint acceptance with a reverberant field can be calculated analytically. Note also that the rectangular panel (surface type 2) has simple sin.sin mode shapes that can be analytically integrated. The program uses the analytical calculation method whenever possible to decrease computer computation time.

$$J_m^2(\omega) = \frac{1}{A^2} \sum_{p'}^{m_x} \sum_{g'}^{n_x} \sum_p^{m_x} \sum_g^{n_x} B_{pg} B_{p'g'} VI(p, p', x_L, \omega) VI(g, g', y_L, \omega)$$

where

if $i \neq j$ and $i+j$ is odd,

$$VI(i, j, l, \omega) = 0, 0$$

If $i \neq j$ and ij is even,

$$VI(i, j, l, \omega) = \frac{1}{(j^2 - i^2) \pi^2 \beta} \left\{ i (\sin[\pi(\beta + i)] - \sin[\pi(\beta - i)]) \right. \\ \left. - j (\sin[\pi(\beta + j)] - \sin[\pi(\beta - j)]) \right\}$$

If $i=j$,

$$VI(i, j, l, \omega) = \frac{1}{2j \pi^2 \beta} [\sin[\pi(\beta + j)] - \sin[\pi(\beta - j)]] \\ + \frac{1}{2\pi \beta} [\text{Si}[\pi(\beta + j)] + \text{Si}[\pi(\beta - j)]] \\ + \frac{1}{\pi^2 (j^2 - \beta^2)} [1 - (-1)^j \cos(\pi \beta)]$$

In all above,

$$\beta = l\omega / \pi c_0$$

$$\text{CIN}(z) = \int_0^z \frac{1 - \cos x}{x} dx$$

and

$$\text{SI}(z) = \int_0^z \frac{\sin x}{x} dx$$

2a. PRESSURE FIELD TYPE 2: AERODYNAMIC TURBULENCE

2b. SURFACE PRESSURE FIELD CORRELATION EQUATION

$$C(x-x', y-y', \omega) = C_x(x-x', \omega) C_y(y-y', \omega)$$

$$C_x(x-x', \omega) = \text{EXP}[-\alpha_x K_x |x-x'|] \cos(K_x(x-x'))$$

$$C_y(y-y', \omega) = \text{EXP}[-\alpha_y K_y |y-y'|] \cos(K_y(y-y'))$$

α_x, α_y - correlation constants

K_x, K_y - factored wave numbers

Assign

$$\text{Ex}(1,1) = \alpha_x$$

$$\text{Ex}(2,1) = K_x/K$$

$$\text{Ex}(3,1) = \alpha_y$$

$$\text{Ex}(4,1) = K_y/K$$

so

$$\text{NPFC} = 4$$

The correlation constants and the factored wave numbers can be varied to match the field. Only a small amount of data is available regarding near field jet and rocket noise. VIN requires the user to input these factors. As a point of reference, however, Cockburn and Jolly obtained the following average values for jet and rocket noise field impressed on the rocket itself. (1968 U. S. Air Force Flight Dynamics Laboratory report TR-68-2.)

$$K_x = K$$

$$K_y = 0.382 K$$

$$\alpha_x = 0.092$$

$$\alpha_y = 0.3125$$

$$B(i,j) = \frac{2(i^2+j^2)^2}{\pi^3 j^3 i^3 D(i) D(j)} \propto B_1^2 ((\alpha^2-1)B_1^2+1)$$

$$D(i) = ((\alpha^2+1)(B/i)^2 + 1)^2 - 4(B/i)^2$$

$$D(j) = ((\alpha^2+1)(B/j)^2 + 1)^2 - 4(B/j)^2$$

$$B_1 = \left(\frac{2}{i^2+j^2} \right)^{1/2} B$$

$$B = l\omega/\pi C_0$$

If $i=j$, then

$$VI(j,j,l,\alpha,k) = A(j) (1 - (-1)^j e^{-\pi\alpha B} \cos \pi B) \\ + B(j) (-1)^j e^{-\pi\alpha B} \sin \pi B + C(j)$$

$$A(j) = \frac{2}{(j\pi)^2 D^2(j)} \left(((\alpha^2-1)(B/j)^2 + 1)^2 - 4(\alpha B^2/j^2)^2 \right)$$

with the x-direction parallel to the axis of the thrust and y perpendicular to the axis of the thrust and $K = \omega/c$ with c the speed of sound in the fluid medium.

2c. GENERALIZED FORCE CALCULATIONS

If the mode shape is given by equation, the joint acceptance is generally numerically calculated. If the mode shape is given by Fourier series, the joint acceptance with a pressure field of aerodynamic turbulence can be calculated analytically.

$$J_m^2(\omega) = \frac{1}{A^2} \sum_{p'}^{M \times N} \sum_{\bar{g}'}^{M \times N} \sum_p^{M \times N} \sum_{\bar{g}}^{M \times N} m B_{p\bar{g}} m B_{p'\bar{g}'} VI(p, p', x_L, \alpha_x, k_x) \\ \cdot VI(\bar{g}, \bar{g}', y_L, \alpha_y, k_y)$$

Note also that the simple rectangular panel (surface type 2) can be represented by a one term, where

if $i \neq j$, then

$$VI(i, j, \ell, \alpha, k) = A(i, j) (1 - (-1)^i e^{-\pi \alpha \ell} \cos \pi \ell) \\ + B(i, j) ((-1)^i e^{-\pi \alpha \ell} \sin \pi \ell)$$

and

$$A(i, j) = \frac{(i^2 + j^2)^2}{2\pi^2 i^3 D(i) D(j)} \left(((\alpha^2 - 1) B_i^2 + 1)^2 - 4(\alpha B_i^2)^2 \right. \\ \left. - \left(\frac{j^2 - i^2}{j^2 + i^2} \right)^2 \right)$$

and

$$B(j) = \frac{8}{(j\pi)^2 D^2(j)} \alpha (B/j)^2 ((\alpha^2 - 1)(B/j)^2 + 1)$$

$$C(j) = \frac{1}{j\pi D(j)} \alpha (B/j) ((\alpha^2 + 1)(B/j)^2 + 1)$$

and the other terms as previously defined in this section.

3a. **PRESSURE FIELD TYPE 3: RANDOM AMPLITUDE PLANE WAVE FIELD**

3b. **SURFACE PRESSURE CORRELATION EQUATIONS**

$$C(x-x', y-y', \omega) = C_x(x-x', \omega) C_y(y-y', \omega)$$

$$C_x(x-x', \omega) = \cos\left(\frac{\omega_0}{C_0}(x-x') \cos \theta\right)$$

$$C_y(y-y', \omega) = \cos\left(\frac{\omega_0}{C_0}(y-y') \cos \theta\right)$$

where c - speed of sound in fluid medium
 ω_0 - frequency of wave
 Θ - incidence angle of wave on surface

ASSIGN :

$$EX(1, IS) = \Theta$$

$$\text{so } NPFC = 1$$

3c. GENERALIZED FORCE CALCULATIONS

Since the excitation is random, the program will require the calculation of the joint acceptance form of generalized force. If the mode shape description is by Fourier series, the joint acceptance can be analytically calculated in the following manner.

$$J_m^2(\omega) = \frac{1}{A^2} \sum_p^{M \times} \sum_{\delta}^{N \times} \sum_{p'}^{M \times} \sum_{\delta'}^{N \times} m B_{p\delta} m B_{p'\delta'} .$$

$$= \iiint \int C(x-x', y-y', \omega) \sin\left(\frac{p\pi x}{x_L}\right) \sin\left(\frac{\delta\pi y}{y_L}\right)$$

$$dy' dx' dy dx$$

The integral for the progressive wave field becomes

$$J_m^2(\omega) = \frac{1}{A^2} \sum_P \sum_{\delta} \sum_{P'} \sum_{\delta'} m B_{P\delta} m B_{P'\delta'} \\ \cdot VI(P, P', x_L, \omega) \cdot VI(\delta, \delta', y_L, \omega)$$

where

if $i \neq j$ and $i+j$ is odd,

$$VI(i, j, l, \omega) = 0$$

If $i+j$ is even,

$$VI(i, j, l, \omega) = \frac{2}{\pi^2} i j (1 - (-1)^j \cos \pi \beta) / \\ (i^2 - \beta^2)(j^2 - \beta^2)$$

AND

$$\beta = l\omega / \pi c_0 * \cos \theta$$

4a. PRESSURE FIELD TYPE 4: POINT FORCE EXCITATION

This "pressure field" type allows a direct point excitation of the structure. While it is not a pressure field, it must have a surface uniquely associated with it to mesh with the general organization of the program.

4b. SURFACE PRESSURE CORRELATION EQUATIONS

$$F(x_o, \omega) = \delta(x_o - x_f) F(x_f, \omega)$$

where

x_o - x, y, z COORDINATE

x_f - x, y, z COORDINATE OF FORCE APPLICATION

$$\begin{aligned} \delta(x_o - x_f) &= 0, \text{ IF } x_o \neq x_f \\ &= 1, \text{ IF } x_o = x_f \end{aligned}$$

ω - FREQUENCY

Assign

$$\left. \begin{aligned} EX(1, IS) &= x_f \\ EX(2, IS) &= y_f \end{aligned} \right\}$$

both in the surface component coordinate system used in the mode shape definition.

So

$$NPFC = 2$$

4c. GENERALIZED FORCE CALCULATIONS

The force description can be either deterministic or random. For deterministic excitation, the generalized force squared is

$$|Q_m^{bl}(\omega)|^2 = |F(x_f, \omega)|^2 \cdot \psi_m^2(x_f)$$

where $\psi_m(x_f)$ mode shape of structure at point x_f .

A modified generalized force is required in the calculation routines in the form of a joint acceptance with an associated $S_{pbl}(\omega)$:

$$J_m^f(\omega) = \psi_m^2(x_f) / A^2$$

where A is area of the surface to which the force is applied.

The $|F(x_f, \omega)|^2$ is given in the data as the external pressure, $S_{pbl}(\omega)$

Random excitation simply requires using the expected value of $|F(x_f, \omega)|^2$.

APPENDIX D

PROGRAM LISTING

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10RIA 12/14/83-19:11(42,)

```
1. C*****
2. C*          VEHICAL INTERIOR NOISE PREDICTION
3. C*          (VIN)
4. C*
5. C* VIN IS A GENERAL PURPOSE PROGRAM DESIGNED FOR STRUCTURAL/ACOUSTIC
6. C* INTERACTION ANALYSIS OF PROBLEM OF THE ENCLOSED CAVITY TYPE.
7. C* THE CODE IS IN ASCII LEVEL 10R1 FORTRAN. THE CODE WAS IMPLEMENTED
8. C* AND TESTED ON THE UNIVAC 1108 AT THE MARSHALL SPACE FLIGHT CENTER
9. C* IN HUNTSVILLE ALABAMA. ANALYSIS AND CODING BY MARK R. PETTITT FOR
10. C* FOR MSFC WITH S. GUEST AND T. NESMAN TECHNICAL PROJECT OFFICERS.
11. C*
12. C*****
13. COMMON MC(1),AC(1),DAC(1)
14. COMMON/STRG25/INMUD,ISVDA(40),ISVDX(40)
15. COMMON /AREA1/IOP,MOP(4),IPRE(4),IN,IOUT
16. COMMON/AREA2/L0,L1,L2,L3,L4,L5,L6,L7,L8,L9,L10,L11,L12,L13,
17. & L14,L15,L16,L17,L18
18. COMMON/AREA3/ZERO,EPS,BW
19. COMMON/AREA4/NEV,NFS,NPECT,NTOBT,NVT,NST,MXVT,MXST,NMT,
20. & NSMT,MXT,NXT,NAMMCT,NSEACT
21. COMMON/AREA5/NPROB,NPROBN,NTAPE,NTAPE,LBAND,MBAND,IMBAND
22. COMMON/AREA6/NMO,NG,DFQY,NI,ER
23. COMMON/AREA7/WI,WF,NWS
24. COMMON/AREA8/RO,CO,VOL,PREF,PI
25. COMMON/AREA9/FAC,PSI,DPI,DN,UP
26. DOUBLE PRECISION DAC
27. CHARACTER*8 DATCD
28. CHARACTER*8 UN
29. PI=3.1415926
30. IN=5
31. IOUT=6
32. C**** INITIALIZE CONSTANTS
33. DATA WI,WF,NWS/0.0,0.0,0.0/
34. DATA NAMMC,N00,NOM,NMO,NG,DFQY,NI,ER/0.0,0.0,0.0,0.0,0.0,0.0,0.0/
35. C****
36. C***** ASSIGN FILE REFERENCE NUMBERS *****
37. L0=10
38. L1=11
39. L2=12
40. L3=13
41. L4=14
42. L5=15
43. L6=16
44. L7=17
45. L8=18
46. L9=19
47. L10=20
48. L11=21
49. L12=22
50. L13=23
51. L14=24
52. L15=25
53. L16=26
54. L17=27
55. L18=28
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56. C*****LOAD DATA CARDS A-E1*****
57. CALL DATALD(MC(IIVTYP),AC(IV),AC(IVTM),AC(IVNODC),AC(IV
58. EORG),AC(IIVM),MC(IISTYP),AC(IAREA),AC(ISTM),
59. EAC(ISNODC),AC(ISORG),MC(IISV),MC(IMASSU),AC(ISC),AC(IBPG),
60. EMC(IISURC),MC(IIVOLC),AC(ICENTF),MC(INSTOR),MC(INSDAT),AC(IZMDAT),
61. EAC(IZNDAT),MC(IIPF),AC(ISPL),AC(IEIX),AC(IGNODE),AC(IOTM),
62. EAC(IONODC),AC(IORG),AC(IAREAO),MC(IGEMO),MC(IIOCM),MC(IITSEAO),MC
63. E(IITOTYP),MC(IIFE),NAM,NV,MXV,NSMX,NS,MXS,NMS,MNSS,NTOB,NAMMC,NN,
64. ENSC,NOM,MX,NX,MFE,AC(I,MH),MC(INM),NOO,NSEAC,NPEC,NAS,
65. E AC(IGNCWN),MC(IIFEN))
66. IF(MOP(1).EQ.0)DATCD='DELETE'
67. IF(MOP(1).GT.0)DATCD='KEEP'
68. UN='UNKNOWN'
69. IF(NPROB.EQ.0.AND.MOP(1).EQ.1)UN='NEW'
70. C*****DEFINE ALL MASS STORAGE FILES *****
71. MNR=NfV
72. MRS=MXVT*3*NVT+3*NVT+3*3*NVT+3*NVT+NVT+(MXST*3*NST+3*3*NST+3*NST+
73. E NST)*2+NVT+NST+NST+NST*2+NST+NST*10+NST+NTOB+NST+NST+NN*3+
74. E NST*MXST*2+NVT*MXVT,NTOB*2
75. OPEN(1,FILE='L1',ACCESS='DIR',RECL=MRS,RCDS=MNR,STATUS=UN)
76. MNR=NfV*3
77. IL=NST*NAMT
78. IL1=4*NAMT*NVT
79. MRS=MAX0(IL,IL1)
80. IL=NTOB+NST
81. MRS=MAX0(MRS,IL)
82. OPEN(12,FILE='L2',ACCESS='DIR',RECL=MRS,RCDS=MNR,STATUS=UN)
83. IF(NAMT.EQ.0) GOTO 3
84. MNR=3*NfV
85. MRS=NAMT
86. OPEN(13,FILE='L3',ACCESS='DIR',RECL=MRS,RCDS=MNR,STATUS=UN)
87. MNR=NfV
88. MRS=NVT*NAMT
89. OPEN(14,FILE='L4',ACCESS='DIR',RECL=MRS,RCDS=MNR,STATUS=UN)
90. MNR=NAMT*NVT*NfV
91. MRS=NAMMCT
92. IF(NAMMCT.NE.0)
93. EOPEN(15,FILE='L5',ACCESS='DIR',RECL=MRS,RCDS=MNR,STATUS=UN)
94. MNR=NVT*NfV
95. MRS=NAMT
96. IF(NAMT.NE.0)
97. EOPEN(16,FILE='L6',ACCESS='DIR',RECL=MRS,RCDS=MNR,STATUS=UN)
98. MNR=NfV*NSMT*NST
99. MRS=NAMT
100. IF(NAMT.NE.0)
101. EOPEN(17,FILE='L7',ACCESS='DIR',RECL=MRS,RCDS=MNR,STATUS=UN)
102. 3 CONTINUE
103. MNR=4*NfS
104. MRS=NTOB
105. OPEN(18,FILE='L8',ACCESS='DIR',RECL=MRS,RCDS=MNR,STATUS=UN)
106. MNR=2*NfS
107. MRS=NSMT*3
108. IF(NSMT.EQ.0)GOTO 4
109. OPEN(19,FILE='L9',ACCESS='DIR',RECL=MRS,RCDS=MNR,STATUS=UN)
110. MNR=NfS*NSMT
111. MRS=NTOB
112. OPEN(110,FILE='L10',ACCESS='DIR',RECL=MRS,RCDS=MNR,STATUS=UN)

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113.      MNR=NFS
114.      MRS=MXT*NXT*NSMT
115.      4  CCNTINUE
116.      IF(MXT.NE.0)
117.      COPEN(L12,FILE='L12',ACCESS='DIR',RECL=MRS,RCDS=MNR,STATUS=UN)
118.      MNR=NFS
119.      MRS=NS*EACT*NTOB
120.      IF(INSEACT.NE.0)
121.      COPEN(L13,FILE='L13',ACCESS='DIR',RECL=MRS,RCDS=MNR,STATUS=UN)
122.      MNR=3*NFS
123.      MRS=NTOB
124.      OPEN(L14,FILE='L14',ACCESS='DIR',RECL=MRS,RCDS=MNR,STATUS=UN)
125.      MNR=NFS
126.      MRS=NTOB*2
127.      OPEN(L15,FILE='L15',ACCESS='DIR',RECL=MRS,RCDS=MNR,STATUS=UN)
128.      MNR=NAM
129.      MRS=N00*NMO
130.      IF(N00.NE.0)
131.      COPEN(L16,FILE='L16',ACCESS='DIR',RECL=MRS,RCDS=MNR,STATUS=UN)
132.      MNR=N00*2
133.      MRS=NAM*NMO
134.      IF(NMO.NE.0)
135.      COPEN(L17,FILE='L17',ACCESS='DIR',RECL=MRS,RCDS=MNR,STATUS=UN)
136.      C      FILE L18 DEFINED IN DATAD IF NEEDED UNDER SECTION 0.
137.      C****  ALLOCATE SPACE FOR ARRAYS THAT ARE USED BOTH IN THE MODAL
138.      C****  AND SEA PORTIONS OF THE PROGRAM
139.      5  IL=4XS*3*NS+NS*NS*NSC+NMS*NPFC+NTOB*NSEAC+MXS*3*N00+N00*NTOB+
140.      6  NTOB+NS*NTOB
141.      CALL ALLOC(AC,IL)
142.      ISNODC=IL+1
143.      IAREA=ISNODC+MXS*3*NS
144.      ISC=IAREA+NS
145.      IEX=ISC+NS*NSC
146.      IWMH=IEX+NMS*NPFC
147.      IONODC=IWMH+NTOB*NSEAC
148.      IAREA0=IONODC+MXS*3*N00
149.      ICENTE=IAREA0+N00
150.      IZMDAT=ICENTE+NTOB
151.      IZNDAT=IZMDAT+NTOB
152.      IL1=NS+NMS*MNSS+NS+N00+N00*2+NMS+NMS+NMS+NMS
153.      CALL IALLOC(MC,IL1)
154.      IISTYP=IL1+1
155.      IMASSU=IISTYP+NS
156.      IISV=IMASSU+NMS*MNSS
157.      IIOTYP=IISV+NS
158.      IIGEMO=IIOTYP+N00
159.      INSDAT=IIGEMO+N00*2
160.      INSTOR=INSDAT+NMS
161.      IISEAO=INSTOR+NMS
162.      IIPF=IISEAO+NMS
163.      C****  ALLOCATE SPACE FOR THOSE ARRAYS TO BE USED IN THE MODAL ANALYSIS
164.      C****  PORTION OF VIN ONLY
165.      M=NV*NAM
166.      IF(M.LT.NSMX)M=NSMX
167.      IL2=3*3*NS+3*NS+3*3*N00+3*N00+MXV*3*NV+3*3*NV+3*NV+NV+NN*3+NAM.
168.      6  4*NAM*NV+NAM*NV+3*NSMX+3*NMO*N00+NTOB+NSMX+M+MX*NX*
169.      6  NSMX+NTOB*2+NTOB*2+NTOB

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170.      CALL ALLOC(AC,IL2)
171.      ISTM=IL2+1
172.      ISORG=ISTM+3*3*AS
173.      IOTM=ISORG+3*NS
174.      IOORG=IOTM+3*3*N00
175.      IVNODC=IOORG+3*N00
176.      IVTM=IVNODC+MXV*3*NV
177.      IVORG=IVTM+3*3*NV
178.      IV=IVORG*3*NV
179.      IGNODE=IV+NV
180.      IWNMC=IGNODE+NN*3
181.      IWN=IWNMC+NAM
182.      IRMN=IWN+4*NAM*NV
183.      IWM=IRMN+NV*NAM
184.      IWM0=IWM+3*NSMX
185.      ISPL=IWM0+3*NMO*N00
186.      IBNDWN=ISPL+NTOB
187.      IBNDWM=IBNDWN+NTOB*2
188.      IZM=IBNDWM+NTOB*2
189.      IAMN=IZM+NSMX
190.      IBPQ=IAMN+M
191.      ISPLT=IBPQ+MX*NX*NSMX
192.      IF(NG.EQ.0)MCP=0
193.      IF(NG.NE.0)MCP=(NAM/NG+1)*NV
194.      IL3=MXS*NS+MXV*NV+MXS*N00+NV*NMS+NAM*NMS+MFE+MCP*NV
195.      CALL IALLOC(MC,IL3)
196.      IISURC=IL3+1
197.      IIVOLC=IISURC+MXS*NS
198.      IIOCM=IIVOLC+MXV*NV
199.      IIVTYP=IIOCM+MXS*N00
200.      INM=IIVTYP+NV
201.      IINDPN=INM+NMS
202.      IIFE=IINDPN+NAM
203.      IIFEN=IIFE+NMS
204.      IIOPMD=IIFEN+MFE
205.      CALL DATAL(MC(IIVTYP),AC(IV),AC(IVTM),AC(IVNODC),AC(IV
206.      ORG),AC(IWM),MC(IISTYP),AC(IAREA),AC(ISTM),
207.      &AC(ISNODC),AC(ISORG),MC(IISV),MC(IMASSU),AC(ISC),AC(IBPQ),
208.      &MC(IISURC),MC(IIVOLC),AC(ICENTE),MC(INSTOR),MC(INSDAT),AC(IZMDAT),
209.      &AC(IZNDAT),MC(IIPF),AC(ISPL),AC(IEX),AC(IGNODE),AC(IOTM),
210.      &AC(IONODC),AC(IOORG),AC(IAREA0),MC(IIGEMO),MC(IIOCM),MC(IISEAO),MC
211.      &(IIVTYP),MC(IIFE),NAM,NV,MXV,NSMX,NS,MXS,NMS,MNSS,NTOB,NAM,MC,NN,
212.      &NSC,NOM,MX,NX,MFE,AC(IWM),MC(INM),N00,NSEAC,NPFC,NAS,
213.      &AC(IBNDWN),MC(IIFEN))
214.      IF(LBAND.EQ.MBAND)GOTO 65
215.      LN=1
216.      CALL FROCAL(AC(IWN),AC(IWM0),AC(IWM),AC(IW1),AC(IW2),AC(IW3),
217.      &AC(IW4),MC(INM),IPRE,AC(IVNODC),AC(IONODC),AC(ISNODC),
218.      &AC(ICENTE),MC(INSDAT),MC(INSTOR),MC(IIVTYP),MC(IIVTYP),
219.      &MC(IISTYP),AC(ISC),MC(IIFE),NAM,NV,NMO,N00,NSMX,NMS,NS,MXV,
220.      &MXS,MBAND,CO,PI,NFS,NTOB,NSC,IOP,L8,L9,MXM,LN)
221.      IL4=4*MXM
222.      CALL ALLOC(AC,IL4)
223.      IW1=IL4+1
224.      IW2=IW1+MXM
225.      IW3=IW2+MXM
226.      IW4=IW3+MXM

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227.      LN=2
228.      CALL FROCAL(AC(IWN),AC(IWMO),AC(IWM),AC(IW1),AC(IW2),AC(IW3),
229.      &AC(IW4),MC(INM),IPRE,AC(IVNODC),AC(IIONODC),AC(IISNODC),
230.      &AC(ICENTF),MC(INS DAT),MC(INSTOR),MC(IIVTYP),MC(IIOTYP),
231.      &MC(IISTYP),AC(IISC),MC(IIFE),NAM,NV,NMO,NGO,NSMX,NMS,NS,MXV,
232.      &MXS,MBAND,CO,PI,NFS,NTOB,NSC,IOP,L8,L9,MXM,LN)
233.      CALL FREE(AC,IL4)
234.      IF(INV.EQ.1.OR.IPRE(1).EQ.1) GOTO 10
235.      N=NOM*NGO
236.      N1=N-1
237.      IL4=NOM*NGO+2*(NAM*NMO)+NMO+NMO
238.      CALL ALLOC(AC,IL4)
239.      IEIMTX=IL4+1
240.      IVLNM=IEIMTX+NOM*NGO
241.      IVLNM1=IVLNM+NAM*NMO
242.      IVAL=IVLNM1+NAM*NMO
243.      ITOT=IVAL+NMO
244.      IL4A=N**2+N1*N
245.      WRITE(6,*)DFQY,DFQY,DFQY
246.      CALL DALLOC(DAC,IL4A)
247.      ID=1+IL4A
248.      IA=ID+N**2*4
249.      WRITE(6,*)IDFQY,DFQY
250.      LN=1
251.      IF(NPROB.NE.0)GOTO 101
252.      CALL PRMCAL(AC(IVLNM1),AC(IBM),AC(IVMNP),AC(IRMN),AC(IVLNM),
253.      &AC(ICN),AC(IZANN),AC(IRJA),AC(IAMN),AC(IAMO),AC(IOTM),AC(IOORG),
254.      &AC(IIONODC),AC(IWM),AC(ISTM),AC(ISORG),AC(ISNODC),AC(IWNMC),
255.      &AC(IWN),AC(IVTM),AC(IVORG),AC(IVNODC),MC(IGEMO),MC(IISV),
256.      &MC(IIOTYP),MC(IISTYP),MC(IIVTYP),MC(IMASSU),MC(INM),MC(INS DAT),
257.      &MC(INSTOR),AC(IBM),AC(IBM),AC(ICENTF),AC(IZNDAT),MC(IIFE),
258.      &AC(IEX),AC(IPNMC),MC(IINDPN),AC(IAREA),AC(IAREAO),NOM,NGO,NAM,
259.      &NMS,MX,NX,NS,MSS,NTOB,NMX,NPFC,MXS,NV,MXV,NAMMC,NMO
260.      &S,AC(IV),AC(IISC),NSC,AC(IZMDAT),AC(IZM),LN)
261.      101 CONTINUE
262.      WRITE(6,*)DFQY
263.      CALL MULCV(AC(IWNMC),AC(IEIMTX),DAC(IA),DAC(ID),
264.      &AC(IVLNM),AC(IVLNM1),AC(IWN),AC(IWMO),MC(IGEMO),AC(IAREAO),
265.      &AC(IV),AC(ICENTF),NAM,NAMMC,NGO,NOM,N1,N,NMO,NV,N1,DFQY,NTOB,
266.      &LBAND,MBAND,L16,L17,MC(IIOPMD),MCP,NG,AC(IVAL),AC(ITOT))
267.      CALL FREE(AC,IL4)
268.      CALL DFREE(DAC,IL4A)
269.      C**** ALLOCATE SPACE FOR THE MODAL ANALYSIS PARAMETER CALCULATIONS
270.      10 I1=0
271.      IF(IOP.EQ.2.OR.IOP.EQ.4)I1=1
272.      NIP=0
273.      N=NTOB
274.      N1=NTOB
275.      IF(I1.EQ.1)N1=NWS
276.      IF(I1.EQ.1)N=NWS
277.      IF(I1.EQ.1)N1=0
278.      IL4=NAMMC+NAM+NAM+NAM+NTOB+NS*NAM+N+N*N*NV,N1+N1*NV+N1P
279.      CALL ALLOC(AC,IL4)
280.      IPNMC=IL4+1
281.      IZANN=IPNMC+NAMMC
282.      IVMNPA=IZANN+NAM
283.      IVLNM=IVMNPA+NAM

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284. IRJA=IVLNM*NAM
285. ICN=IRJA+NTOB
286. IANS=ICN*NS*NAM
287. IANSS=IANS+N
288. IBNS=IANSS*N*NV
289. IBNSS=IBNS+N
290. ITBND=IBNSS*N*NV
291. IF (NV.EQ.1.OR.IPRE(1).EQ.1) GOTO 20
292. IL5=NAM*NMO+NAM*NOM
293. CALL ALLOC(AC,IL5)
294. IVLNM=IL5+1
295. IEIMTX=IVLNM+NAM*NMO
296. CALL VPNC(AC(IWNMC),AC(IWN),NAM,NV,MC(IIGEMO),NOO,NOM,AC(IAREAO
297. &),NMO,AC(IEIMTX),AC(IPNMC),MC(IINDPN),NAMMC,AC(IVLNM),AC(IV),
298. ENPROBN,NAMT,NVT,L5,L6,L16,L17,MC(IIPMD),MCP,NG)
299. CALL FREE(AC,IL5)
300. C**** CALCULATE THE REQUIRED MODAL ANALYSIS PARAMETERS AND PLACE ON
301. C**** CORRECT MASS STORAGE FILES
302. 20 LN=2
303. CALL PRMCAL(AC(IVLNM),AC(IBM),AC(IVMNP),AC(IRMN),AC(IVLNM),
304. &AC(ICN),AC(IZANN),AC(IRJA),AC(IAMN),AC(IWMO),AC(IOTM),AC(IOORG),
305. &AC(IONODC),AC(IWM),AC(ISTM),AC(ISORG),AC(ISNODC),AC(IWNMC),
306. &AC(IWN),AC(IVTM),AC(IVORG),AC(IVNODC),MC(IIGEMO),MC(IISV),
307. &MC(IITOTYP),MC(IISTYP),MC(IIVTYP),MC(IMASSU),MC(INM),MC(INS DAT),
308. &MC(INSTOR),AC(IBM),AC(IBM),AC(ICENTF),AC(IZNDAT),MC(IIPF),
309. &AC(IE),AC(IPNMC),MC(IINDPN),AC(IAREA),AC(IAREAO),NOM,NOO,NAM,
310. ENMS,MX,NX,NS,MNSS,NTOB,NSMX,NPFC,MXS,NV,MXV,NAMMC,NMO
311. &AC(IV),AC(ISC),NSC,AC(IZMDAT),AC(IZM),LN)
312. CALL BNDGAL(AC(IBM),AC(IBM),AC(IWNMC),AC(IWN),AC(IZMDAT),
313. &AC(IZANN),MC(INM),AC(ICENTF),MC(INSTOR),NS,NTOB,NAM,NSMX,NMS,
314. &BW,EPS,NFS,IPRE,MC(IISTYP),L8,L9,L15,MC(INS DAT),IOP,NPROB)
315. LN=3
316. IF(IOP.EQ.5) GOTO 15
317. CALL PRMCAL(AC(IVLNM),AC(IBM),AC(IVMNP),AC(IRMN),AC(IVLNM),
318. &AC(ICN),AC(IZANN),AC(IRJA),AC(IAMN),AC(IWMO),AC(IOTM),AC(IOORG),
319. &AC(IONODC),AC(IWM),AC(ISTM),AC(ISORG),AC(ISNODC),AC(IWNMC),
320. &AC(IWN),AC(IVTM),AC(IVORG),AC(IVNODC),MC(IIGEMO),MC(IISV),
321. &MC(IITOTYP),MC(IISTYP),MC(IIVTYP),MC(IMASSU),MC(INM),MC(INS DAT),
322. &MC(INSTOR),AC(IBM),AC(IBM),AC(ICENTF),AC(IZNDAT),MC(IIPF),
323. &AC(IE),AC(IPNMC),MC(IINDPN),AC(IAREA),AC(IAREAO),NOM,NOO,NAM,
324. ENMS,MX,NX,NS,MNSS,NTOB,NSMX,NPFC,MXS,NV,MXV,NAMMC,NMO
325. &AC(IV),AC(ISC),NSC,AC(IZMDAT),AC(IZM),LN)
326. WRITE(6,*)NSMX,NSMX,NSMX
327. WRITE(6,*)NSMX,NSMX,NSMX,NSMX
328. 15 CALL MDLPRM(AC(IWNMC),AC(IVMNP),AC(IZANN),AC(IRMN),
329. &AC(IRJA),AC(IWM),MC(INM),AC(ISPL),AC(ICENTF),MC(IISTYP),
330. &MC(INSTOR),NAMT,NPROBN,NFS,NTAPE,NSMX,NMS,NSMT,PREF,
331. &NAM,NV,NS,NTOB,AC(IZMDAT),LBAND,MBAND,L4,L8,L9,L10)
332. WRITE(6,*)NSMX,NSMX,NSMX,NSMX,NSMX
333. 102 CONTINUE
334. C**** CALCULATE THE VEHICAL INTERIOR NOISE (VIN):BAND AVERAGE
335. II=0
336. IF(IOP.EQ.1.OR.IOP.EQ.3) II=1
337. IF(II.EQ.1) CALL CALC(AC(IANS),AC(IANSS),AC(IBNS),AC(IBNSS),
338. &AC(IWNMC),AC(IZANN),AC(IVMNP),AC(IRMN),MC(INM),AC(IAREA),AC(IWM),
339. &AC(IVLNM),AC(ISPL),AC(IRJA),AC(IZM),AC(ICENTF),MC(INSTOR),NV
340. &NAM,NS,NMS,NSMX

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341.      E,NFS,NSMT,LBAND,MBAND,NTOB,NPROBN,BW,ZERO,PREF,VOL,RO,CO,PI,L7,
342.      L8,L9,L10,IOUT,AC(ISPL),MC(IISTYP),NST)
343.      C**** CALCULATE THE VEHICAL INTERIOR NOISE (VIN):DESCRETE FREQUENCIES
344.      II=0
345.      IF(IOP.EQ.2.OR.IOP.EQ.4)II=1
346.      IF(II.EQ.1)CALL DFCALC(AC(IANS),AC(IANSS),
347.      EAC(IWNMC),AC(IZANN),AC(IWMNPA),AC(IRMH),MC(INM),AC(IAREA),AC(IWM),
348.      EWF,WI,AC(IVLNM),AC(ISPL),AC(IRJA),AC(IZM),AC(ICENTF),MC(INSTOR),N
349.      E,NSMT,NAM,NS,NMS,NSMX,NF,MC(IISTYP),NWS,NTOB,NPROBN,ZERO,PREF,
350.      E VOL,RO,CO,PI,NST,L7,L8,L9,L10,IOUT,BW,AC(ITBND))
351.      C
352.      C**** CALCULATE THE REVERBERATION TIME
353.      IF(IOP.EQ.6) CALL REVER(AC(IWNMC),AC(ICN),AC(IZNDAT),AC(IZNDI),
354.      EAC(IWMNPA),AC(ICENTF),NAM,NTOB,LBAND,MBAND,NS,RO,CO,VOL,BW,NPROBN
355.      E,DT,NFV,AC(ICZANN),IOUT,L2)
356.      C*****
357.      C*****
358.      C**** TRANSITION TO SEA EQUATIONS
359.      CALL FREE(AC,IL4)
360.      65 CALL IFREE(MC,IL3)
361.      WRITE(6,*)IHBAND,IHBAND
362.      CALL FREE(AC,IL2)
363.      WRITE(6,*)LBAND,LBAND
364.      IF(MBAND.EQ.IHBAND)GOTO 100
365.      IF(IOP.NE.1)GOTO 100
366.      C****
367.      NV1=NV+1
368.      IL4=(NS*NTOB)*2+NV+NMS*NTOB+NTOB*NV
369.      E *NMS*NTOB
370.      CALL ALLOC(AC,IL4)
371.      IRJA=IL4+1
372.      IRJARV=IRJA+NS*NTOB
373.      ISPL=IRJARV+NS*NTOB
374.      IANSS=ISPL+NTOB*NMS
375.      IZMD1=IANSS+NV*NTOB
376.      IL5=NMS*NTOB
377.      CALL IALLOC(MC,IL5)
378.      IMD=IL5+1
379.      IL5A=NV*NV1
380.      CALL DALLOC(DAC,IL5A)
381.      IC=IL5A+1
382.      CALL HFREQ(AC(IRJA),AC(ISPL),AC(ICENTF),AC(IAREA),
383.      EAC(IAREA0),MC(IMD),AC(IZMD1),MC(IMASSU),AC(IRJARV),
384.      EAC(IZNDAT),MC(IISTYP),MC(IIGEMO),MC(IISV),DAC(IC
385.      E),NV,NV1,IHBAND,NTOB,NS,NDO,NMS,MNSS,BW,NFS,AC(IAN
386.      ESS),AC(IEX),MBAND,AC(IWMH),MC(INSDAT),MC(INSTOR),MC(IISEAO),MC(I
387.      EIPF),NFV,NSEAC,NPFC,NPROBN,MOP,L2,L8,L13,L14)
388.      CALL SEAPRM(AC(IRJA),AC(IRJARV),MC(IMD),
389.      E AC(IZMD1),AC(ICENTF),AC(ISPL),MBAND,IHBAND,NTOB,NMS,NT,PF,
390.      E MC(INSTOR),AC(IZNDAT),IOUT,NS,MC(IISEAO))
391.      CALL SEARES(NVOL,NV,PREF,NTOB,MBAND,IHBAND,AC(IANSS),
392.      EAC(ICENTF),IOUT)
393.      100 CONTINUE
394.      110 CONTINUE
395.      DO 111 I=10,28
396.      111 CLOSE(I,STATUS=DATCD)
397.      CALL EXIT

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398.

END

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,S XX.DATALD,XX.

10RIA 12/14/83-18:38(34,)

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1.  C*****
2.  SUBROUTINE DATALD(IVTYP,V,VTM,VNODC,VORG,
3.  *WM,ISTYP, AREA,STM,SNODC,SORG,ISV,MASSUR,SC,BPQ,ISURCM,
4.  *IVOLCM,CENTF,NSTOR,NSDAT,ZNDATA,ZNDATA,IPF,SPL,EX,GNODE,
5.  * OTM,ONODC,OORG,AREAO,IGEMOV,IOCM,ISEAO,IOTYP,IFE,
6.  *NAM,NV,MXV,NSMX,NS,MXS,NMS,MNSS,NTOB,NAMMC,NN,NSC,
7.  *NOM,MX,NX,MFE,WMH,NM,NOO,NSEAC,NPFC,NAS,BNDWN,IFEN)
8.  COMMON MC(1),AC(1)
9.  COMMON /AREA1/IOP,MOP(4),IPRE(4),IN,IOUT
10. COMMON/AREA2/LO,L1,L2,L3,L4,L5,L6,L7,L8,L9,L10,L11,L12,L13,
11. & L14,L15,L16,L17,L18
12. COMMON/AREA3/ZERO,EPS,BW
13. COMMON/AREA4/NFV,NFS,NPFC,NTOB,NVT,NST,MXVT,MXST,NAMT,
14. & NSMT,MXT,NXT,NAMMCT,NSEACT
15. COMMON/AREA5/NPROB,NPROBN,MTAPE,NTAPE,LBAND,MBAND,IHB,ND
16. COMMON/AREA6/NMO,NG,DFQY,NI,ER
17. COMMON/AREA7/WI,Wf,NWc
18. COMMON/AREA8/RO,CO,VOL,PREF,PI
19. COMMON/AREA9/FAC,PSI,DPI,DN,UP
20. DOUBLE PRECISION FAC(57),PSI(60),DPI,DN,UP
21. DIMENSION IVTYP(NV),V(NV),VTM(3,3,NV),
22. *VNODC(MXV,3,NV),VORG(3,NV),WM(3,NSMX),
23. *ISTYP(NMS),AREA(NS),STM(3,3,NS),SNODC(MXS,3,NS),
24. *SORG(3,NS),ISV(NS),MASSUR(MNSS,NMS),SC(NSC,NS),BPQ(MX,
25. *NX,NSMX), ISURCM(MXS,NS),IVOLCM(MXV,NV),CENTF(NTOB),NSTOR(NMS)
26. DIMENSION NSDAT(NMS),ZNDATA(NTOB),SPL(NTOB),ZNDATA(NTOB,NS),
27. & WMH(NSEAC,NTOB),EX(NPFC,NMS),NM(NMS),GNODE(NN,3),OTM(3,3,NOO),
28. & ONODC(MXS,3,NOO),OORG(3,NOO),AREAO(NOO),IGEMOV(2,NOO),
29. & ISEAO(NMS),IOCM(MXS,NOO),IOTYP(NOO),IPF(NMS),IFE(NMS)
30. & ,BNDWN(NTOB,2),IFEN(MFE)
31. CHARACTER*80 TITLE
32. CHARACTER*75 STITLE
33. CHARACTER*10 UN
34. DATA DPI/3.14159263589793D0/,UP,DN/1.000000500,0.999999500/
35. INP=5
36. IOUT=6
37. PI=3.1415926
38. IN=5
39. READ(IN,5)TITLE
40. 5 FORMAT(A80)
41. READ(IN,10)STITLE
42. 10 FORMAT(A75)
43. WRITE(IOUT,15)TITLE
44. 15 FORMAT('1',A80)
45. WRITE(IOUT,20)STITLE
46. 20 FORMAT(5X,A75)
47. C**** A. OPTION SELECTION
48. READ(IN,*)IX
49. READ(IN,*)IOP
50. READ(IN,*)MOP
51. READ(IN,*)IPRE
52. READ(IN,*)NPROB,NPROBN,MTAPE,NTAPE
53. UN='UNKNOWN'
54. IF(NPROB.EQ.0.AND.MOP(1).EQ.1)UN='NEW'
55. OPEN(LO,FILE='LO',ACCESS='DIR',RECL=40,RCDS=60,STATUS=UN)

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56. C*** SECTION FOR TAPE READ OF FIRST FILE ***
57. IF(NPROB.EQ.0)GOTO 21
58. IR=1
59. READ(LQ*IR)NTAPE,NFV,NFS,NPFCT,NTOB,NVT,NST,MXVT,
60. & MXST,NAMT,NSMT,MXT,NXT,NAMMCT,NSEACT,NPA,NSA
61. IR=1+NPROB
62. READ(LQ*IR)NN,NS,NMS,MNSS,NAS,MXS,NSMX,NSC,NV,MXV,
63. & NAM,NTOB,MFE,MX,NX,NSEAC,NPFC,NWS,NOO,LBAND,MBAND,IHBAND,RO,CO,
64. &VOL,PREF,ZERO,EPS,BW
65. C**** B.SIZING PARAMETERS FOR NEW DATA FILE
66. 21 READ(IN,*)IX
67. IF(IX.EQ.0) GO TO 25
68. READ(IN,*)NFV,NFS,NPFCT,NTOB,NVT,NST,MXVT,MXST,NAMT,
69. & NSMT,MXT,NXT,NAMMCT,NSEACT
70. 25 CONTINUE
71. C**** C.RANGE : FREQUENCY DOMAIN
72. READ(IN,*)IX
73. IF(IX.EQ.0)GOTO26
74. READ(IN,*)LBAND,MBAND,IHBAND,BW
75. C**** D. RANGE : DESCRETE FREQUENCY
76. 26 READ(IN,*)IX
77. IF(IX.EQ.0) GO TO 30
78. READ(IN,*)WI,WF,NWS
79. 30 CONTINUE
80. C**** E.TOLERANCES
81. READ(IN,*)IX
82. IF(IX.EQ.0) GOTO 35
83. READ(IN,*) ZERO,EPS
84. 35 CONTINUE
85. IF(NPROB.EQ.0) GO TO 40
86. WRITE(6,*)NTAPE,NFV,NFS,NSEACT,NN,NS,NMS,NWS
87. C****
88. C**** F. MATRIX SIZING PARAMETERS
89. 40 READ(IN,*)IX
90. IF(IX.EQ.0) GO TO 45
91. READ(IN,*)NN,NS,NMS,MNSS,NAS,MXS,NSMX,NSC,NV,MXV,NAM,NTOB,
92. &MFE,MX,NX,NSEAC,NPFC
93. C**** G. MULTIPLE CAVITY PARAMETERS
94. 45 READ(IN,*) IX
95. IF(IX.EQ.0) GO TO 50
96. READ(IN,*)NAMMC,NOO,NOM,NMO,NG,DFQY,NI,ER
97. 50 RETURN
98. ENTRY DATAL(IVTYP,V,VTM,VNODC,VORG,
99. *WM,ISTYP, AREA,STM,SNODC,SORG,ISV,MASSUR,SC,BPQ,ISURCM,
100. *IVOLCM,CENTF,NSTOR,NSDAT,ZMDATA,ZNDATA,IPF,SPL,EX,GNODE,
101. * OTH,ONODC,OORG,AREAO,IGEMOV,IOCM,ISEAO,IOTYP,IFE,
102. *NAM,NV,MXV,NSMX,NS,MXS,NMS,MNSS,NTOB,NAMMC,NN,NSC,
103. *NOM,MX,NX,MFE,WMH,NM,NOO,NSEAC,NPFC,NAS,BNDWN,IFEN)
104. DO 51 I=1,NMS
105. 51 ISEAO(I)=0
106. IF(NPROB.EQ.0) GOTO 55
107. C***** READ FROM MASS AND PLACE INTO MEMORY *****
108. IR=NPROB
109. READ(L1*IR)VNODC,VTM,VORG,IVTYP,ONODC,OTH,OORG,IOTYP,
110. &SNODC,STM,SORG,ISTYP,V,AREAO,AREA,IGEMOV,ISV,MASSUR,NSDAT,CENTF
111. &IFE,ISEAO,GNODE,IOCM,ISURCM,IVOLCM,BNDWN
112. DO 54 I=1,NS

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113.      54 NSTOR(I)=NSDAT(I)
114.      IF(IOP.EQ.5)GOTO 55
115.      IR=2*NFS+NPROB
116.      READ(L2*IR)ZNDATA
117.      DO 53 I=1,NMS
118.      IR=NFS+NSDAT(I)
119.      53 READ(L8*IR)(SC(J,I),J=1,NSC)
120.      C*****
121.      55 CONTINUE
122.      C**** H. OPENING/VOLUME RELATIONSHIPS: IGEMOV
123.      READ(IN,*)IX
124.      IF(IX.EQ.0) GO TO 65
125.      DO 65 IX=1, NOO
126.      READ(IN,*)ISUR,IGEMOV(1,ISUR),IGEMOV(2,ISUR)
127.      65 CONTINUE
128.      C**** I. OPENING DESCRIPTION
129.      READ(IN,*)IX
130.      IF(IX.EQ.0) GOTO 70
131.      DO 70 IX=1,NOO
132.      READ(IN,*)I,IOTYP(I),AREAO(I),(IOCH(J,I),J=1,MXS)
133.      70 CONTINUE
134.      C**** J. STRUCTURAL DATA FILE ACCESS AND STORAGE LOCATIONS
135.      READ(IN,*)IX
136.      IF(IX.EQ.0) GO TO 75
137.      READ(IN,*)(NSDAT(I),I=1,NMS)
138.      READ(IN,*)(NSTOR(I),I=1,NMS)
139.      75 CONTINUE
140.      C**** K. GLOBAL NODE POINTS
141.      READ(IN,*)IX
142.      IF(IX.EQ.0) GO TO 80
143.      DO 80 IX=1,NN
144.      READ(IN,*)I,(GNODE(I,J),J=1,3)
145.      80 CONTINUE
146.      C**** L. SURFACE DESCRIPTION
147.      READ(IN,*)IX
148.      IF(IX.EQ.0)GO TO 85
149.      DO 85 IX=1,NS
150.      READ(IN,*) ISUR,ISTYP(ISUR),AREA(ISUR),(ISURCM(I,ISUR
151.      1),I=1,MXS)
152.      85 CONTINUE
153.      DO 86 I=1,NMS
154.      IF(NSDAT(I).EQ.0) GO TO 86
155.      IR=NSDAT(I)
156.      READ(L8*IR)NM(I)
157.      86 CONTINUE
158.      C**** M. MASTER SURFACE/SURFACE RELATIONSHIPS : ISV
159.      READ(IN,*)IX
160.      IF(IX.EQ.0) GO TO 90
161.      DO 90 I=1,NMS
162.      READ(IN,*)IS,(MASSUR(J,IS),J=1,MNSS)
163.      90 CONTINUE
164.      C**** N. STRUCTURAL CONSTANTS: MODAL ANALYSIS
165.      READ(IN,*)IX
166.      IF(IX.EQ.0)GOTO 95
167.      DO 95 ISUR=1,NMS
168.      IF(NSDAT(ISUR).EQ.0)READ(IN,*)IS, (SC(J,IS),J=1,NSC)
169.      IR=NFS+NSTOR(ISUR)

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170.      IF(NSDAT(ISUR).EQ.0)WRITE(L8*IR)(SC(J,ISUR),J=1,NSC)
171.      IF(NSDAT(ISUR).NE.0)READ(IN,*)IS
172.      IF(ISTYP(ISUR).NE.7)GOTO 95
173.      IF(NSDAT(ISUR).NE.0)GOTO 95
174.      DO 97 I=1,INT(SC(1,ISUR))
175.      READ(IN,*)(BPQ(1,J,I),J=1,9)
176.      97 BPQ(1,1,I)=BPQ(1,1,I)*2.*PI
177.      NM(ISUR)=NINT(SC(1,ISUR))
178.      IR=NSTOR(ISUR)
179.      WRITE(L12*IR)BPQ
180.      WRITE(L9*IR)((BPQ(1,J,I),J=1,3),I=1,NSMX)
181.      95 CONTINUE
182.      DO 94 IS=1,NMS
183.      IF(NSDAT(IS).EQ.0)GOTO 94
184.      IR=NSDAT(IS)+NFS
185.      READ(L8*IR)(SC(J,IS),J=1,NSC)
186.      94 CONTINUE
187.      C**** 0. STRUCTURAL MODAL DATA
188.      NFEDS=0
189.      DO 96 I=1,NMS
190.      96 IFE(I)=0
191.      READ(IN,*)IX
192.      IF(IX.EQ.0)GOTO 101
193.      READ(IN,*)NFEDS
194.      MNR=NFEDS
195.      MRS=6*MFE+2*NSMT+NSMT*3*MFE
196.      OPEN(L18,FILE='L18',ACCESS='DIR',RECL=MRS,RCDS=MNR,STATUS=UN)
197.      MMAX=(1.*MFE)**.5*1.5
198.      NMAX=MMAX
199.      C*** ASSIGN CORE STORAGE
200.      IF(MOP(4).NE.1)IL=MFE+MFE+NSMX*3*MFE+MMAX+NMAX+MMAX*NMAX+MFE
201.      & +MFE+MFE
202.      IF(MOP(4).EQ.1)IL=MFE+MFE+MFE+MFE+NSMX*3*MFE
203.      CALL ALLOC(ARK,IL)
204.      ID1=IL+1
205.      ID2=ID1+MFE
206.      ID3=ID2+MFE
207.      IVM=ID3+MFE
208.      ISN=IVM+MFE
209.      IX1=ISN+NSMX*MFE*3
210.      IX2=IX1+MMAX
211.      IY=IX2+NMAX
212.      ITK=IY+MMAX*NMAX
213.      DO 99 I=1,NMS
214.      READ(IN,*)IS,IFE(IS),NFEN,SL1,SL2
215.      IF(IFE(IS).EQ.0)GOTO 99
216.      READ(IN,*)(IFEN(J),J=1,NFEN)
217.      C*** TEMPORARILY USE STM AND SORG TO TRANSLATE F.E. GLOBAL COORDINATES
218.      C*** TO SURFACE LOCAL COORDINATES
219.      READ(IN,*)(STM(1,K,IS),K=1,3),SORG(1,IS)
220.      READ(IN,*)(STM(2,K,IS),K=1,3),SORG(2,IS)
221.      READ(IN,*)(STM(3,K,IS),K=1,3),SORG(3,IS)
222.      CALL FEDAT(IS,NFEN,NFEDS,NS,NMS,IFE,IFEN,ISTYP,STM,SORG,WM,NSTOR,
223.      & BPQ,MOP,AREA,AC(ID1),AC(ID2),AC(ID3),AC(IVM),AC(ISN),AC(IX1),
224.      & AC(IX2),AC(ITK),AC(IY),MX,NX,MFE,NSMX,SL1,SL2,MMAX,NMAX,L9,L12
225.      & ,L18)
226.      99 CONTINUE

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227.      101 CONTINUE
228.      C**** P.  STRUCTURAL CONSTANTS: STATISTICAL ENERGY ANALYSIS
229.      READ(IN,*)IX
230.      IF(IX.EQ.0)GOTO 110
231.      DO 110 IS=1,NMS
232.      DO 109 I=1,NSEAC
233.      DO 109 J=1,NTOB
234.      109 WMH(I,J)=0.0
235.      READ(IN,*) ISUR,ISEAO(ISUR)
236.      IF(NSDAT(ISUR).NE.0)GOTO 110
237.      IF(ISEAO(ISUR).EQ.0)GOTO 110
238.      DO 105 NOB=1,NTOB
239.      READ(IN,*)K,(WMH(J,K),J=1,NSEAC)
240.      IF(WMH(1,NOB).LT.0.0) GOTO 106
241.      105 CONTINUE
242.      C**STORE DATA IN APPROPRIATE MASS STORAGE FILE
243.      106 IR=NSTOR(IS)
244.      WRITE(L13*IR)WMH
245.      C
246.      110 CONTINUE
247.      C**** Q.  VOLUME DESCRIPTION
248.      READ(IN,*) IX
249.      IF(IX.EQ.0)GOTO 115
250.      VOL=0.0
251.      DO 115 I=1,NV
252.      READ(IN,*)NVOL,IVTYP(NVOL),V(NVOL),(IVOLCM(J,NVOL),J=1,MXV)
253.      VOL=VOL+V(NVOL)
254.      115 CONTINUE
255.      C**** R.  ACOUSTIC CONSTANTS
256.      READ(IN,*)IX
257.      IF(IX.EQ.0) GOTO 120
258.      READ(IN,*)RO,CO,PREF
259.      120 CONTINUE
260.      C**** S.  ACOUSTIC MODAL DATA
261.      READ(IN,*)IX
262.      C**** NOT YET ALLOWED BY PROGRAM
263.      C****
264.      C**** T.  SURFACE/VOLUME RELATIONSHIPS
265.      READ(IN,*)IX
266.      IF(IX.EQ.0)GOTO 130
267.      DO 130 I=1,NS
268.      READ(IN,*)ISUR,ISV(ISUR)
269.      130 CONTINUE
270.      C**** U.  SURFACE ABSORPTION
271.      READ(IN,*)IX
272.      IF(IX.EQ.0)GOTO 136
273.      134 DO 135 I=1,NS
274.      READ(IN,*) ISUR,IX
275.      IF(IX.EQ.0) GOTO 135
276.      READ(IN,*) (ZNDATA(J,ISUR),J=1,NTOB)
277.      135 CONTINUE
278.      IR=2*NFX+NPROBN
279.      WRITE(L2*IR)ZNDATA
280.      C**** V.  STRUCTURAL DAMPING
281.      136 READ(IN,*)IX
282.      IF(IX.EQ.0) GOTO 140
283.      DO 140 I=1,NMS

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284.      READ(IN,*)ISUR,IX
285.      IF(IX.EQ.0) GOTO 140
286.      READ(IN,*)(ZMDATA(J),J=1,NTOB)
287.      IR=2*NFS+NSTOR(I)
288.      WRITE(L8*IR) ZMDATA
289.      140 CONTINUE
290.      C**** W. EXTERNAL SOUND PRESSURE LEVEL: FREQUENCY DOMAIN
291.      READ(IN,*)IX
292.      IF(IX.EQ.0) GOTO 145
293.      DO 145 I=1,NMS
294.      READ(IN,*)ISUR,IX
295.      IF(IX.EQ.0) GOTO 145
296.      READ(IN,*)(SPL(J),J=1,NTOB)
297.      IR=3*NFS+NSTOR(I)
298.      WRITE(L8*IR) SPL
299.      145 CONTINUE
300.      C**** X. EXTERNAL PRESSURE FIELD DESCRIPTION CONSTANTS
301.      READ(IN,*)IX
302.      IF(IX.EQ.0) GOTO 150
303.      DO 150 I=1,NMS
304.      READ(IN,*)ISUR,IPF(ISUR)
305.      IF(IPF(ISUR).EQ.0) GOTO 150
306.      READ(IN,*)(EX(J,ISUR),J=1,NPFC)
307.      150 CONTINUE
308.      C**** Y. BAND CENTER FREQUENCIES
309.      READ(IN,*)IX
310.      IF(IX.EQ.0) GOTO 155
311.      READ(IN,*)(CENTF(NOBI),NOBI=1,NTOB)
312.      DO 155 I=1,NTOB
313.      CENTF(I)=CENTF(I)*2.0*PI
314.      155 CONTINUE
315.      C**** Z. REVERBERATION TIME
316.      C****
317.      READ(IN,*)IX
318.      IF(IX.EQ.0) GOTO 156
319.      C**** GENERATE COORDINATE SYSTEM TRANSFORMATION MATRICIES
320.      156 CONTINUE
321.      IF(IPRE(1).EQ.1) GOTO 1110
322.      CALL TRANS
323.      CALL OTRANS
324.      C**** OUTPUT THE INPUT DATA
325.      1110 CONTINUE
326.      IF(NPROB.EQ.0) NPA=0
327.      IF(NPROB.EQ.0) NSA=0
328.      DO 1200 IS=1,NMS
329.      IF(NSDAT(IS).EQ.0.AND.NSTOR(IS).NE.0.AND.NPROB.NE.NPROBN)NSA=NSA+1
330.      1200 CONTINUE
331.      IF(NPROB.NE.NPROBN)NPA=NPA+1
332.      IR=1
333.      WRITE(LD*IR)NTAPE,NFV,NFS,NPFC,NTOBT,NVT,NST,MXVT,MXST,
334.      & NAMT,NSMT,MXT,NXT,NAMMCT,NSEACT,NPA,NSA
335.      IR=1+NPROBN
336.      WRITE(LD*IR)NN,NS,NMS,MNSS,NAS,MXS,NSMX,NSC,NV,MXV,NAM,NTOB,
337.      & MFE,MX,NX,NSEAC,NPFC,NWS,NOO,LBAND,MBAND,IHBAND,RO,CO,
338.      & VOL,PREF,ZERO,EPS,BW
339.      DO 1300 IS=1,NMS
340.      IR=1+10*NSTOR(IS)

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341.      IF (NSTOR(IS).NE.0) WRITE (LO*IR) ISTYP (IS), NM (IS), NSC, IPF (IS), LBAND
342.      & , MBAND, IHBAND, NSEAC, ISEA0 (IS)
343.      1300 CONTINUE
344.      WRITE (6,*) NV, NV, NV, NPROB, NPROBN
345.      IR=NPROBN
346.      WRITE (L1*IR) VNODC, VTM, VORG, IVTYP, ONODC, OTM, OORG, IOTYP,
347.      & SNODC, STM, SORG, ISTYP, V, AREA0, AREA, IGEMOV, ISV, MASSUR, NSTOR, CENTF
348.      & , IFE, ISEA0, GNODE, IOCM, ISURCM, IVOLCM, BNDWN
349.      DO 157 I=1, NTOB
350.      CENTF (I)=CENTF (I)/2./PI
351.      157 CONTINUE
352.      IF (MOP (2).EQ.0) CALL OINPUT
353.      J=0
354.      DO 158 I=1, NOO
355.      IF (IOTYP (I).EQ.3) J=1
356.      158 CONTINUE
357.      DO 160 I=1, NV
358.      IF (IVTYP (I).EQ.3) J=1
359.      160 CONTINUE
360.      IF (J.EQ.1) CALL FCTCAL
361.      DO 165 I=1, NTOB
362.      CENTF (I)=CENTF (I)*2.*PI
363.      165 CONTINUE
364.      1111 RETURN
365.      C*****
366.      C*****
367.      SUBROUTINE OINPUT
368.      C*
369.      C* CARD INPUT IS REFLECTED TO OUTPUT DEVICE
370.      C*
371.      DIMENSION INC (22), VNC (7)
372.      WRITE (IOUT, 100)
373.      C**** LOAD AND OUTPUT DATA SET #1.
374.      IR=1
375.      READ (LO*IR) (INC (I), I=1, 17)
376.      WRITE (IOUT, 110) (INC (I), I=1, 17)
377.      C**** LOAD AND OUTPUT DATA SET #2.
378.      WRITE (IOUT, 120)
379.      DO 25 J=1, NPA
380.      IR=1+J
381.      READ (LO*IR) (INC (I), I=1, 22), (VNC (I), I=1, 7)
382.      WRITE (IOUT, 130) J
383.      WRITE (IOUT, 140) (INC (I), I=1, 22), (VNC (I), I=1, 7)
384.      25 CONTINUE
385.      C**** LOAD AND OUTPUT DATA SET #3.
386.      WRITE (IOUT, 150)
387.      DO 50 IS=1, NSA
388.      IR=1+10*IS
389.      READ (LO*IR) (INC (I), I=1, 9)
390.      WRITE (IOUT, 160) IS
391.      WRITE (IOUT, 170) (INC (I), I=1, 9)
392.      50 CONTINUE
393.      C***** FORMAT STATEMENTS
394.      100 FORMAT (55X, 'DATA FILE INDEX' / 54X, '*****')
395.      110 FORMAT (26X, 'TAPE SIZING: DATA SET #1.' / 61X, 'NTAPE - ', I3 / 61X,
396.      & 'NFBV - ', I3 / 61X,
397.      * 'NFS - ', I3 / 61X, * 'NPFCT - ', I3 / 61X, * 'NTOBT - ', I3 / 61X,

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398.      *NVT      = ',I3/61X,'NST      = ',I3/61X,
399.      *MXVT     = ',I3/61X,'MXST     = ',I3/61X,'NAMT     = ',I3/61X,
400.      *NSMT     = ',I3/61X,'MXT      = ',I3/61X,'NXT      = ',I3/61X,
401.      *NAMMCT   = ',I3/61X,'NSEACT  = ',I3/61X,'NPA      = ',I3/61X, 'NSA
402.      &= ',I3)
403.      120 FORMAT(/26X,'BASIC PROBLEM PARAMETERS : DATA SET #2. ')
404.      130 FORMAT(/34X,'PROBLEM NUMBER = ',I5)
405.      140 FORMAT(61X,'NN      = ',I3/61X,
406.      *NS        = ',I3/61X,'NMS      = ',I3/61X,'MNSS     = ',I3/61X,'NAS =
407.      * ',I3/61X,'MXS      = ',I3/61X,'NSMX      = ',I3/61X,'NSC      = ',I3/61X
408.      *, 'NV          = ',I3/61X,'MXV      = ',I3/61X,'NAM      = ',I3/61X,
409.      *NTOB       = ',I3/61X,'MFE      = ',I3/61X,
410.      *MX         = ',I3/61X,'NX        = ',I3/61X,'NSEAC    = ',I3/61X,
411.      *NPFC       = ',I3/61X,'NWS      = ',I3/61X,'N00      = ',I3/61X,
412.      &'LBAND      = ',I3/61X,'MBAND    = ',I3/61X,'IHBAND    = ',I3/61X,
413.      &'RO         = ',E11.5/61X,'CO      = ',E11.5/61X,'VOL      = ',E11.5
414.      &/61X,'PREF      = ',E11.5/61X,'ZERO    = ',E11.5/61X,'EPS      = '
415.      &,E11.5/61X,'BW          = ',E11.5)
416.      150 FORMAT(/26X,'SURFACE ELEMENTS : DATA SET #3. ')
417.      160 FORMAT(/34X,'FILE SURFACE NUMBER = ',I5)
418.      170 FORMAT(61X,'ISTYP = ',I3/61X,'NM      = ',I3/61X,'NSC      = ',I3
419.      &/61X,'IPF      = ',I3/61X,'LBAND = ',I3/61X,'MBAND = ',I3/61X,
420.      &'IHBAND = ',I3/61X,'NSEAC = ',I3/61X,'ISFAO = ',I3)
421.      WRITE(IOUT,801)
422.      801 FORMAT(45X,'STRUCTURAL / ACOUSTIC INTERACTION ANALYSIS')
423.      A44X,'*****')
424.      WRITE(IOUT,802)
425.      802 FORMAT(/21X,'INPUT DATA'//27X,'A. OPTION SELECTION'//30X,'A1. ',
426.      *ANALYSIS: IOP')
427.      C**** A. OPTION SELECTION
428.      WRITE(IOUT,803) IOP
429.      803 FORMAT(/34X,'IOP = ',I3)
430.      WRITE(IOUT,806) MOP(1),MOP(2),MOP(3),MOP(4)
431.      806 FORMAT(/30X,'A4. SPECIAL OPTIONS: MOP(4)'//34X,
432.      *'CATALOG MASS STORAGE',23X,' - ',I3/34X,'SUPRESS INPUT MIRROR',
433.      (23X,' - ',I3/34X,'USE EXPERIMENTAL CAVITY DAMPING',12X,' - ',I3/
434.      *34X,'USE SHORT BPO CALCULATION ON NEW F.E. DATA - ',I3)
435.      WRITE(IOUT,807) IPRE(1),IPRE(2),IPRE(3),IPRE(4)
436.      807 FORMAT(/30X,'A5. PRECALCULATED DATA: IPRE(4)'//34X,
437.      *ACOUSTIC RESPONSE '14X,' - ',I3/34X,'ACOUSTIC ABSORPTION'
438.      *,14X,' - ',I3/34X,'S/A INTERACTION (ALL SURFACES) - '
439.      *,I3/34X,'GENERALIZED FORCE ',14X,' - ',I3)
440.      WRITE(IOUT,808) NPROB,NPROBN,MTAPE,NTAPE
441.      808 FORMAT(/30X,'A6. DATA ACCESS AND STORAGE'//34X,'NPROB - ',I3/34X
442.      *'NPROBN = ',I3/34X,'MTAPE = ',I3/34X,'NTAPE = ',I3)
443.      C**** B.NEW DATA FILE SIZING PARAMETERS
444.      IF(NPROB.EQ.0.AND.NPROBN.EQ.0) GO TO 900
445.      WRITE(IOUT,809) NFV,NFS,NPFCT,NTOBT,NVT,NST,MXVT,MXST,
446.      & NAMT,NSMT,MXT,NXT,NAMMCT,NSEACT
447.      809 FORMAT('1',26X,'B. DATA TAPE SIZING'//61X,'NFV      = ',I3/61X,
448.      *'NFS        = ',I3/61X,'NPFCT   = ',I3/61X,'NTOBT    = ',I3/61X,
449.      *'NVT        = ',I3/61X,'NST      = ',I3/61X,
450.      *'MXVT       = ',I3/61X,'MXST     = ',I3/61X,'NAMT      = ',I3/61X,
451.      *'NSMT       = ',I3/61X,'MXT      = ',I3/61X,'NXT      = ',I3/61X,
452.      *'NAMMCT    = ',I3/61X,'NSEACT   = ',I3)
453.      900 CONTINUE
454.      C**** C.RANGE : FREQUENCY DOMAIN

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455.      WRITE(IOUT,810) LBAND,MRAND,IMBAND,BW
456.      810 FORMAT(8(/),27X,'C. RANGE : FREQUENCY'//61X,'LBAND - ',I3/61X,
457.      *'MBAND - ',I3/61X,'IMBAND - ',I3/61X,'BW - ',E11.5)
458.      C**** D. RANGE : DELCRETE FREQUENCY
459.      IF(IOP.EQ.2.OR.IOP.EQ.4)WRITE(IOUT,811)WI,WF,NWS
460.      811 FORMAT(8(/),27X,'D. RANGE : DESCRETE FREQ.'//61X,'TI - ',
461.      'E11.5/61X,'WF - ',E11.5/61X,'NWS - ',I3)
462.      C**** E. TOLERANCES
463.      WRITE(IOUT,812) ZERO,EPS
464.      812 FORMAT(8(/),27X,'E. TOLERANCES'//56X,'ZERO - ',E12.5/56X,
465.      *'EPS - ',E11.5)
466.      C**** F. MATRIX SIZING
467.      WRITE(IOUT,813)NN,NS,NMS,MNSS,NAS,MXS,NSMX,NSC,NV,MXV,NAM,NTOB,
468.      *MFE,MX,NX,NSEAC,NPFC
469.      813 FORMAT(8(/),27X,'F. MATRIX SIZING'//61X,'NN - ',I3/61X,
470.      *'NS - ',I3/61X,'NMS - ',I3/61X,'MNSS - ',I3/61X,'NAS - ',
471.      *',I3/61X,'MXS - ',I3/61X,'NSMX - ',I3/61X,'NSC - ',I3/61X,
472.      *',NV - ',I3/61X,'MXV - ',I3/61X,'NAM - ',I3/61X,
473.      *'NTOB - ',I3/61X,'MFE - ',I3/61X,
474.      *'MX - ',I3/61X,'NX - ',I3/61X,'NSEAC - ',I3/61X,
475.      *'NPFC - ',I3)
476.      C**** G. MULTIPLE CAVITY PARAMETERS
477.      IF(NV.EQ.1) GO TO 953
478.      WRITE(IOUT,814) NAMMC,N00,NOM,NMO,DFQY,NI,ER,NG
479.      814 FORMAT('1',27X,'G. MULTIPLE CAVITY PARAMETERS'//61X,
480.      'NAMMC - ',I3/61X,'N00 - ',I3/61X,'NOM - ',I3/61X,
481.      'NMO - ',I3/61X,'DFQY - ',F10.5/61X,'NI - ',I3/61X,
482.      'ER - ',F10.5/61X,'NG - ',I3)
483.      940 CONTINUE
484.      C**** H. OPENING/VOLUME RELATIONSHIPS
485.      WRITE(IOUT,815)
486.      815 FORMAT(8(/),27X,'H. OPENING/VOLUME RELATIONSHIPS'///39X,
487.      'IGEMOV OPENING',5X,'VOLUME (TAIL) VOLUME (HEAD)'//49X,
488.      '*****',5X,'*****')
489.      DO 945 I=1,N00
490.      945 WRITE(IOUT,816)I,IGEMOV(1,I),IGEMOV(2,I)
491.      816 FORMAT(50X,I3,13X,I3,13X,I3)
492.      C**** I. OPENING DESCRIPTION
493.      WRITE(IOUT,817)
494.      817 FORMAT(8(/),27X,'I. OPENING DESCRIPTION'//41X,'OPENING',9X,
495.      *'OPENING',9X,'OPENING'//41X,'NUMBER',11X,'AREA0',12X,
496.      *'TYPE',6X/41X,'*****',7X,'*****',8X,'*****')
497.      DO 950 I=1,N00
498.      WRITE(IOUT,818) I,AREA0(I),IOTYP(I)
499.      818 FORMAT(42X,I3,9X,E11.5,9X,I3)
500.      950 CONTINUE
501.      WRITE(IOUT,819)
502.      819 FORMAT(/40X,'OPENING NUMBER'//40X,'*****')
503.      DO 953 I=1,N00
504.      WRITE(IOUT,820) I
505.      820 FORMAT(/,27X,I3,17X,'NODE'//38X,'ORDER NUMBER',7X,'XC',13X,'YC',
506.      *'13X,'ZC'//38X,'*****')
507.      A*****')
508.      DO 951 J=1,MXS
509.      IF(I0CM(J,I).EQ.0)GOTO 951
510.      WRITE(IOUT,821) J,I0CM(J,I),ONODC(J,1,I),ONODC(J,2,I),
511.      *ONODC(J,3,I)

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512.      821 FORMAT(39X,I3,5X,I3,5X,E11.5,5X,E11.5,5X,E11.5)
513.      951 CONTINUE
514.      WRITE(IOUT,228)
515.      228 FORMAT(/42X,'OTMX',11X,'OTMY',11X,'OTMZ',11X,'OORG'/42X,'****',
516.      A11X,'****',11X,'****',11X,'****')
517.      DO 952 K=1,3
518.      WRITE(IOUT,822)OTM(K,1,I),OTM(K,2,I),OTM(K,3,I),OORG(K,I)
519.      822 FORMAT(39X,E10.2,5X,E10.2,5X,E10.2,5X,E10.2)
520.      952 CONTINUE
521.      953 CONTINUE
522.      C**** J. STRUCTURAL DATA ACCESS AND STORAGE
523.      WRITE(IOUT,823)
524.      823 FORMAT(8(/),27X,'J. STRUCTURAL DATA ACCESS AND STORAGE'//49X,
525.      *'PROBLEM'/49X,'SURFACE'/49X,'NUMBER',10X,'NSDAT',11X,'NSTOR'/49X,
526.      *'*****',9X,'*****',11X,'*****')
527.      DO 954 I=1,NMS
528.      WRITE(IOUT,824)I,NSDAT(I),NSTOR(I)
529.      824 FORMAT(50X,I3,13X,I3,13X,I3)
530.      954 CONTINUE
531.      C**** K. GLOBAL NODE POINTS
532.      WRITE(IOUT,825)
533.      825 FORMAT(8(/),27X,'K. GLOBAL NODE POINTS'//43X,'NODE'/42X,'NUMBER',
534.      *12X,'X',12X,'Y',12X,'Z'/42X,'*****',8X,'*****',3X,
535.      *'*****',3X,'*****')
536.      DO 955 I=1,NN
537.      WRITE(IOUT,826)I,GNODE(I,1),GNODE(I,2),GNODE(I,3)
538.      826 FORMAT(43X,I3,10X,E11.5,3X,E11.5,3X,E11.5)
539.      955 CONTINUE
540.      C**** L. SURFACE DESCRIPTION
541.      WRITE(IOUT,827)
542.      827 FORMAT(8(/),27X,'L. SURFACE DESCRIPTION'//41X,'SURFACE',9X,
543.      *'SURFACE',9X,'SURFACE'/41X,'NUMBER',11X,'AREA',12X,
544.      *'TYPE'/41X,'*****',7X,'*****',8X,'*****')
545.      DO 956 I=1,NS
546.      WRITE(IOUT,828) I,AREA(I),ISTYP(I)
547.      828 FORMAT(42X,I3,9X,E11.5,9X,I3)
548.      956 CONTINUE
549.      WRITE(IOUT,829)
550.      829 FORMAT(/5X,'SURFACE NUMBER'/5X,'*****')
551.      DO 958 I=1,NS
552.      IF(ISTYP(I).EQ.0)GOTO 958
553.      WRITE(IOUT,830) I
554.      830 FORMAT(/,27X,I3,17X,'NODE'/38X,'ORDER  NUMBER',7X,'XC',13X,'YC',
555.      *13X,'ZC'/38X,'*****' ***** ***** ***** *****)
556.      A*****')
557.      DO 957 J=1,MXS
558.      WRITE(IOUT,831) J,ISURCM(J,I),SNODC(J,1,I),SNODC(J,2,I),
559.      *SNODC(J,3,I)
560.      831 FORMAT(39X,I3,5X,I3,5X,E11.5,5X,E11.5,5X,E11.5)
561.      957 CONTINUE
562.      WRITE(IOUT,832)
563.      832 FORMAT(/42X,'STMX',11X,'STMY',11X,'STMZ',11X,'SORG'/42X,'****',
564.      A11X,'****',11X,'****',11X,'****')
565.      DO 958 K=1,3
566.      WRITE(IOUT,833)STM(K,1,I),STM(K,2,I),STM(K,3,I),SORG(K,I)
567.      833 FORMAT(39X,E10.2,5X,E10.2,5X,E10.2,5X,E10.2)
568.      958 CONTINUE

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569. C**** M. MASTER SURFACE/SURFACE RELATIONSHIPS
570. WRITE(IOUT,834)
571. 834 FORMAT(8(/),27X,'M. MASTER SURFACE / SURFACE RELATIONS'//46X,
572. *'MASTER SURFACE',11X,'COMPONENT SURFACE',46X,'*****',11X,
573. *'*****')
574. DO 959 I=1,NMS
575. WRITE(IOUT,835)I,MASSUR(1,I)
576. 835 FORMAT(/51X,I3,24X,I3)
577. DO 959 J=2,MNSS
578. WRITE(IOUT,836) MASSUR(J,I)
579. 836 FORMAT(78X,I3)
580. 959 CONTINUE
581. C**** N. STRUCTURAL CONSTANTS : MODAL ANALYSIS
582. IF(IOP.EQ.5) GOTO 961
583. WRITE(IOUT,837)
584. 837 FORMAT(8(/),27X,'N. STRUCTURAL CONSTANTS'//55X,'SURFACE',6X,
585. A'CONSTANTS'/55X,'*****',6X,'*****')
586. DO 961 I=1,NMS
587. IF(ISTYP(I).EQ.0)GOTO 961
588. WRITE(IOUT,838) I,SC(1,I)
589. 838 FORMAT(/57X,I3,8X,E11.5)
590. DO 960 J=2,NSC
591. WRITE(IOUT,839) SC(J,I)
592. 839 FORMAT(68X,E11.5)
593. 960 CONTINUE
594. 961 CONTINUE
595. C**** O. STRUCTURAL MODAL DATA
596. C****
597. C NO OUTPUT HERE
598. C****
599. C**** P. STRUCTURAL CONSTANTS : STATISTICAL ENERGY ANALYSIS
600. IF(MBAND.EQ.IHBAND)GOTO 969
601. IF(IOP.NE.1) GOTO 969
602. WRITE(IOUT,843)
603. 843 FORMAT(8(/),27X,'P. STRUCTURAL CONSTANTS : SEA'//10X,
604. A'SURFACE',20X,'SEA CODE'/10X,'*****',20X,'*****')
605. IRO=0
606. DO 969 IS=1,NMS
607. IF(ISEAO(IS).EQ.0) GOTO 969
608. IR=NSTOR(IS)
609. IF(IR.EQ.IRO)WRITE(IOUT,1844)IS,IS-1
610. IF(IR.EQ.IRO)GOTO 969
611. READ(113*IR)WMH
612. WRITE(IOUT,844)IS,ISEAO(IS)
613. IRO=IR
614. 844 FORMAT(/,12X,I3,25X,I3)
615. 1844 FORMAT(5X,'DATA FOR SURFACE - ',I3,' SAME AS FOR SURFACE - ',I3)
616. DO 969 NOB=1,NTOB
617. WRITE(IOUT,*)(WMH(J,NOB),J=1,NSEAC)
618. 969 CONTINUE
619. C****
620. C**** Q. VOLUME DESCRIPTION
621. WRITE(IOUT,845)
622. 845 FORMAT(8(/),27X,'Q. VOLUME DESCRIPTION'//41X,'VOLUME',26X,
623. A'VOLUME'/41X,'NUMBER',10X,'VOLUME',11X,'TYPE'
624. A'/41X,'*****',8X,'*****',8X,'*****')
625. DO 970 I=1,NV

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626.      WRITE(IOUT,846) I,V(I),IVTYP(I)
627.      846 FORMAT(42X,I3,9X,E11.5,9X,I3)
628.      970 CONTINUE
629.      WRITE(IOUT,847)
630.      847 FORMAT(/5X,'VOLUME NUMBER'/5X,'*****')
631.      DO 973 I=1,NV
632.      WRITE(IOUT,848) I
633.      848 FORMAT(/,27X,I3,17X,'NODE'/38X,'ORDER   NUMBER',7X,'XC',13X,'YC',
634.      A13X,'ZC'/38X,'*****  *****  *****  *****  *****
635.      A*****')
636.      DO 971 J=1,MXV
637.      WRITE(IOUT,849) J,IVOLCM(J,I),VNODC(J,1,I),VNODC(J,2,I),
638.      *VNODC(J,3,I)
639.      849 FORMAT(39X,I3,5X,I3,5X,E10.2,5X,E10.2,5X,E10.2)
640.      971 CONTINUE
641.      WRITE(IOUT,850)
642.      850 FORMAT(/,42X,'VTMX',11X,'VTMY',11X,'VTMZ',11X,'VORG'/42X,'****',
643.      A11X,'****',11X,'****',11X,'****')
644.      DO 972 K=1,3
645.      WRITE(IOUT,851)VTK(K,1,I),VTK(K,2,I),VTK(K,3,I),VORG(K,I)
646.      851 FORMAT(39X,E10.2,5X,E10.2,5X,E10.2,5X,E10.2)
647.      972 CONTINUE
648.      973 CONTINUE
649.      C**** R. ACOUSTIC CONSTANTS
650.      WRITE(IOUT,852) RO,CO,PREF
651.      852 FORMAT(8(/),27X,'R. ACOUSTIC CONSTANTS'//34X,'RO   - ',E11.5/34X,
652.      *'CO   - ',E11.5/34X,'PREF - ',E7.2)
653.      C**** S. ACOUSTIC MODAL DATA
654.      C****
655.      C**** T. SURFACE/VOLUME RELATIONSHIPS
656.      C****
657.      WRITE(IOUT,854)
658.      854 FORMAT(8(/),27X,'T. SURFACE/VOLUME RELATIONSHIPS'////39X,
659.      & 'ISV      SURFACE',5X,'ADJACENT VOLUME'/49X,'*****',
660.      & 5X,'*****')
661.      DO 979 I=1,NS
662.      WRITE(IOUT,855)I,ISV(I)
663.      855 FORMAT(50X,I3,13X,I3)
664.      979 CONTINUE
665.      IF(IOP.EQ.5) GOTO 111
666.      IF(MOP(3).EQ.1)GOTO 981
667.      C**** U. SURFACE ABSORPTION
668.      WRITE(IOUT,856)
669.      856 FORMAT(8(/),27X,'U. SURFACE ABSORPTION')
670.      DO 981 I=1,NS
671.      WRITE(IOUT,857)
672.      857 FORMAT(/42X,'SURFACE',7X,'FREQUENCY',12X,'LOSS FACTOR'/42X,'*****
673.      A*',7X,'*****',9X,'*****')
674.      WRITE(IOUT,858)I,CENTF(1),ZNDATA(1,I)
675.      858 FORMAT(44X,I3,9X,E11.5,9X,E16.5)
676.      DO 980 J=2,NT0B
677.      WRITE(IOUT,859) CENTF(J),ZNDATA(J,I)
678.      859 FORMAT(56X,E11.5,9X,E16.5)
679.      980 CONTINUE
680.      981 CONTINUE
681.      IF(MOP(3).NE.1) GO TO 982
682.      WRITE(IOUT,860)

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683.      860 FORMAT(8(/),27X,'U. CAVITY DAMPING (EXPERIMENTAL)'/48X,
684.      A'FREQUENCY (HZ)',9X,'LOSS FACTOR'/50X,'*****',9X,
685.      A'*****')
686.      DO 982 I=1,NT08
687.      WRITE(IOUT,861) CENTF(I),ZNDATA(I,1)
688.      861 FORMAT(/50X,E11.5,9X,E16.5)
689.      982 CONTINUE
690.  C**** V. STRUCTURAL DAMPING
691.      WRITE(IOUT,862)
692.      862 FORMAT(8(/),27X,'V. STRUCTURAL DAMPING'/42X,'SURFACE',7X,
693.      A'FREQUENCY',12X,'DAMPING(C/CC)'/42X,'*****',7X,'*****',9X,
694.      A'*****')
695.      IRO=0
696.      DO 984 I=1,NMS
697.      IR=2*NFS+NSTOR(I)
698.      IF(IR.EQ.IRO)WRITE(IOUT,1863)I,I-1
699.      IF(IR.EQ.IRO)GOTO 984
700.      READ(L8*IR) ZMDATA
701.      WRITE(IOUT,863) I,CENTF(1),ZMDATA(1)
702.      863 FORMAT(/44X,I3,9X,E11.5,9X,E16.5)
703.      1863 FORMAT(5X,'DATA FOR SURFACE - ',I3,' SAME AS FOR SURFACE - ',I3)
704.      IRO=IR
705.      DO 983 J=2,NT08
706.      WRITE(IOUT,864) CENTF(J),ZMDATA(J)
707.      864 FORMAT(56X,E11.5,9X,E16.5)
708.      983 CONTINUE
709.      984 CONTINUE
710.  C**** W. EXTERNAL SPL : FREQUENCY DOMAIN
711.      WRITE(IOUT,865)PREF
712.      865 FORMAT(8(/),27X,'W. EXTERNAL SPL'/32X,'SURFACE',13X,
713.      A'FREQUENCY (HZ) SPL(DB,REFC ',E16.5,' )'/32X,'*****',15X,
714.      A'*****',17X,'*****')
715.      IRO=0
716.      DO 986 I=1,NMS
717.      IR=3*NFS+NSTOR(I)
718.      IF(IR.EQ.IRO)WRITE(IOUT,1866)I,I-1
719.      IF(IR.EQ.IRO)GOTO 986
720.      READ(L8*IR) SPL
721.      IRO=IR
722.      WRITE(IOUT,866) I,CENTF(1),SPL(1)
723.      866 FORMAT(/34X,I3,17X,E11.5,17X,E11.5)
724.      1866 FORMAT(5X,'DATA FOR SURFACE - ',I3,' SAME AS FOR SURFACE - ',I3)
725.      DO 985 J=2,NT08
726.      WRITE(IOUT,867) CENTF(J),SPL(J)
727.      867 FORMAT(54X,E11.5,17X,E11.5)
728.      985 CONTINUE
729.      986 CONTINUE
730.  C**** X. PRESSURE FIELD CONSTANTS
731.  C****
732.      WRITE(IOUT,868)
733.      868 FORMAT(8(/),27X,'X. EXTERNAL PRESSURE FIELD CONSTANTS'
734.      &/10X,'SURFACE',20X,'PRESSURE FIELD CONSTANTS'/10X,
735.      &'*****',20X,'*****')
736.      DO 987 IS=1,NMS
737.      WRITE(IOUT,869)IS
738.      IF(IPF(IS).EQ.0)WRITE(IOUT,1869)IS,NSDAT(IS)
739.      IF(IPF(IS).EQ.0)GOTO 987

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740.      869 FORMAT(3X,I3)
741.      1869 FORMAT(5X,'DATA FOR SURFACE - ',I3,' SAME AS FOR FILE SURFACE - '
742.      6,I3)
743.      WRITE(IOUT,870)(EX(J,IS),J=1,NPFC)
744.      870 FORMAT(10E11.5)
745.      987 CONTINUE
746.      155 CONTINUE
747.      111 CONTINUE
748.      RETURN
749.      C*****
750.      SUBROUTINE TRANS
751.      C*****
752.      DO 1000 ISUR=1,NS
753.      IF(ISTYP(ISUR).EQ.0) GOTO 1000
754.      IA=ISURCM(1,ISUR)
755.      IB=ISURCM(2,ISUR)
756.      IC=ISURCM(3,ISUR)
757.      SORG(1,ISUR)=GNODE(IA,1)
758.      SORG(2,ISUR)=GNODE(IA,2)
759.      SORG(3,ISUR)=GNODE(IA,3)
760.      XA1=GNODE(IB,1)-SORG(1,ISUR)
761.      XA2=GNODE(IB,2)-SORG(2,ISUR)
762.      XA3=GNODE(IB,3)-SORG(3,ISUR)
763.      YA1=GNODE(IC,1)-SORG(1,ISUR)
764.      YA2=GNODE(IC,2)-SORG(2,ISUR)
765.      YA3=GNODE(IC,3)-SORG(3,ISUR)
766.      ZA1=(XA2*YA3-XA3*YA2)
767.      ZA2=(XA3*YA1-XA1*YA3)
768.      ZA3=(XA1*YA2-XA2*YA1)
769.      XA=(XA1**2+XA2**2+XA3**2)**.5
770.      YA=(YA1**2+YA2**2+YA3**2)**.5
771.      ZA=(ZA1**2+ZA2**2+ZA3**2)**.5
772.      STM(1,1,ISUR)=XA1/XA
773.      STM(1,2,ISUR)=XA2/XA
774.      STM(1,3,ISUR)=XA3/XA
775.      STM(2,1,ISUR)=YA1/YA
776.      STM(2,2,ISUR)=YA2/YA
777.      STM(2,3,ISUR)=YA3/YA
778.      STM(3,1,ISUR)=ZA1/ZA
779.      STM(3,2,ISUR)=ZA2/ZA
780.      STM(3,3,ISUR)=ZA3/ZA
781.      DO 10 I=1,MXS
782.      X=GNODE(ISURCM(I,ISUR),1)-SORG(1,ISUR)
783.      Y=GNODE(ISURCM(I,ISUR),2)-SORG(2,ISUR)
784.      Z=GNODE(ISURCM(I,ISUR),3)-SORG(3,ISUR)
785.      SNODC(I,1,ISUR)=STM(1,1,ISUR)*X+STM(1,2,ISUR)*Y+STM(1,3,ISUR)*Z
786.      SNODC(I,2,ISUR)=STM(2,1,ISUR)*X+STM(2,2,ISUR)*Y+STM(2,3,ISUR)*Z
787.      SNODC(I,3,ISUR)=STM(3,1,ISUR)*X+STM(3,2,ISUR)*Y+STM(3,3,ISUR)*Z
788.      10 CONTINUE
789.      STM(1,1,ISUR)=XA1/XA
790.      STM(2,1,ISUR)=XA2/XA
791.      STM(3,1,ISUR)=XA3/XA
792.      STM(1,2,ISUR)=YA1/YA
793.      STM(2,2,ISUR)=YA2/YA
794.      STM(3,2,ISUR)=YA3/YA
795.      STM(1,3,ISUR)=ZA1/ZA
796.      STM(2,3,ISUR)=ZA2/ZA

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797.      STM(3,3,ISUR)=ZA3/ZA
798.      1000 CONTINUE
799.      DO 2000 NVOL=1,NV
800.      IA=IVOLCM(1,NVOL)
801.      IB=IVOLCM(2,NVOL)
802.      IC=IVOLCM(3,NVOL)
803.      VORG(1,NVOL)=GNODE(IA,1)
804.      VORG(2,NVOL)=GNODE(IA,2)
805.      VORG(3,NVOL)=GNODE(IA,3)
806.      XA1=GNODE(IB,1)-VORG(1,NVOL)
807.      XA2=GNODE(IB,2)-VORG(2,NVOL)
808.      XA3=GNODE(IB,3)-VORG(3,NVOL)
809.      YA1=GNODE(IC,1)-VORG(1,NVOL)
810.      YA2=GNODE(IC,2)-VORG(2,NVOL)
811.      YA3=GNODE(IC,3)-VORG(3,NVOL)
812.      ZA1=(XA2*YA3-XA3*YA2)
813.      ZA2=(XA3*YA1-XA1*YA3)
814.      ZA3=(XA1*YA2-XA2*YA1)
815.      XA=(XA1**2+XA2**2+XA3**2)**.5
816.      YA=(YA1**2+YA2**2+YA3**2)**.5
817.      ZA=(ZA1**2+ZA2**2+ZA3**2)**.5
818.      VTM(1,1,NVOL)=XA1/XA
819.      VTM(1,2,NVOL)=XA2/XA
820.      VTM(1,3,NVOL)=XA3/XA
821.      VTM(2,1,NVOL)=YA1/YA
822.      VTM(2,2,NVOL)=YA2/YA
823.      VTM(2,3,NVOL)=YA3/YA
824.      VTM(3,1,NVOL)=ZA1/ZA
825.      VTM(3,2,NVOL)=ZA2/ZA
826.      VTM(3,3,NVOL)=ZA3/ZA
827.      DO 20 I=1,MXV
828.      X=GNODE(IVOLCM(I,NVOL),1)-VORG(1,NVOL)
829.      Y=GNODE(IVOLCM(I,NVOL),2)-VORG(2,NVOL)
830.      Z=GNODE(IVOLCM(I,NVOL),3)-VORG(3,NVOL)
831.      VNODC(I,1,NVOL)=VTM(1,1,NVOL)*X+VTM(1,2,NVOL)*Y+VTM(1,3,NVOL)*Z
832.      VNODC(I,2,NVOL)=VTM(2,1,NVOL)*X+VTM(2,2,NVOL)*Y+VTM(2,3,NVOL)*Z
833.      VNODC(I,3,NVOL)=VTM(3,1,NVOL)*X+VTM(3,2,NVOL)*Y+VTM(3,3,NVOL)*Z
834.      20 CONTINUE
835.      2000 CONTINUE
836.      111 CONTINUE
837.      RETURN
838.      SUBROUTINE OTRANS
839.      C*****
840.      DO 1000 ISUR=1,N00
841.      IA=IOCM(1,ISUR)
842.      IB=IOCM(2,ISUR)
843.      IC=IOCM(3,ISUR)
844.      OORG(1,ISUR)=GNODE(IA,1)
845.      OORG(2,ISUR)=GNODE(IA,2)
846.      OORG(3,ISUR)=GNODE(IA,3)
847.      XA1=GNODE(IB,1)-OORG(1,ISUR)
848.      XA2=GNODE(IB,2)-OORG(2,ISUR)
849.      XA3=GNODE(IB,3)-OORG(3,ISUR)
850.      YA1=GNODE(IC,1)-OORG(1,ISUR)
851.      YA2=GNODE(IC,2)-OORG(2,ISUR)
852.      YA3=GNODE(IC,3)-OORG(3,ISUR)
853.      ZA1=(XA2*YA3-XA3*YA2)

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854.      ZA2=(XA3*YA1-XA1*YA3)
855.      ZA3=(XA1*YA2-XA2*YA1)
856.      XA=(XA1**2+XA2**2+XA3**2)**.5
857.      YA=(YA1**2+YA2**2+YA3**2)**.5
858.      ZA=(ZA1**2+ZA2**2+ZA3**2)**.5
859.      OTM(1,1,ISUR)=XA1/XA
860.      OTM(1,2,ISUR)=XA2/XA
861.      OTM(1,3,ISUR)=XA3/XA
862.      OTM(2,1,ISUR)=YA1/YA
863.      OTM(2,2,ISUR)=YA2/YA
864.      OTM(2,3,ISUR)=YA3/YA
865.      OTM(3,1,ISUR)=ZA1/ZA
866.      OTM(3,2,ISUR)=ZA2/ZA
867.      OTM(3,3,ISUR)=ZA3/ZA
868.      DO 10 I=1,MXS
869.      X=GNODE(IOCMI(I,ISUR),1)-OORG(1,ISUR)
870.      Y=GNODE(IOCMI(I,ISUR),2)-OORG(2,ISUR)
871.      Z=GNODE(IOCMI(I,ISUR),3)-OORG(3,ISUR)
872.      ONODC(I,1,ISUR)=OTM(1,1,ISUR)*X+OTM(1,2,ISUR)*Y+OTM(1,3,ISUR)*Z
873.      ONODC(I,2,ISUR)=OTM(2,1,ISUR)*X+OTM(2,2,ISUR)*Y+OTM(2,3,ISUR)*Z
874.      ONODC(I,3,ISUR)=OTM(3,1,ISUR)*X+OTM(3,2,ISUR)*Y+OTM(3,3,ISUR)*Z
875.      10 CONTINUE
876.      OTM(1,1,ISUR)=XA1/XA
877.      OTM(2,1,ISUR)=XA2/XA
878.      OTM(3,1,ISUR)=XA3/XA
879.      OTM(1,2,ISUR)=YA1/YA
880.      OTM(2,2,ISUR)=YA2/YA
881.      OTM(3,2,ISUR)=YA3/YA
882.      OTM(1,3,ISUR)=ZA1/ZA
883.      OTM(2,3,ISUR)=ZA2/ZA
884.      OTM(3,3,ISUR)=ZA3/ZA
885.      1000 CONTINUE
886.      111 CONTINUE
887.      RETURN
888.      C*****
889.      SUBROUTINE FCTCAL
890.      FAC(1)=1.00
891.      FAC(2)=1.00
892.      DO 4 J=2,56
893.      FAC(J+1)=FAC(1)*DFLOAT(J)
894.      FAC(1)=FAC(J+1)
895.      4 CONTINUE
896.      FAC(1)=1.00
897.      PSI(1)=-.5772156649015329000
898.      DO 10 J=1,60
899.      PSI(J)=PSI(1)+1.00/DFLOAT(J)
900.      PSI(1)=PSI(J)
901.      10 CONTINUE
902.      PSI(1)=-.5772156649015329000
903.      RETURN
904.      END

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,S XX.FEDAT,XX.

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10R1A 12/14/83-18:38(16,)
1. SUBROUTINE FEDAT(IS,NFEN,NFEDS,NS,NMS,IFE,IFEN,ISTYP,STM,SORG,
2. & WM,NSTOR,BPQ,MOP,AREA,D1,D2,D3,VM,SN,X1,X2,TK,Y,MX,NX,MFE,NSMX,
3. & SL1,SL2,MMAX,NMAX,L9,L12,L18)
4. DIMENSION IFE(NMS),IFEN(MFE),ISTYP(NS),STM(3,3,NS),SORG(3,NS),
5. & WM(3,NSMX),NSTOR(NMS),BPQ(MX,NX,NSMX),MOP(4),AREA(NS),D1(MFE),
6. & D2(MFE),D3(MFE),VM(MFE),SN(MFE,3,NSMX),X1(MMAX),X2(NMAX),TK(MFE),
7. & Y(MMAX,NMAX)
8. PI=3.14159
9. C**** LOAD THE F.E. DATA FOR THE SURFACE
10. IR=IFE(IS)
11. READ(18*IR)NFES,NSM,(I,D1(I),D2(K),D3(I),I8=1,NFES),
12. & (I,VM(I),I8=1,NFES),
13. & (I,WM(1,I),(I,SN(K,J,I),J=1,NFES),K=1,3),I8=1,NSM)
14. C*** PROCESS THE F.E. DATA
15. IR=NSTOR(IS)
16. WRITE(19*IR)WM
17. C***** ASSUME THE RESULTANT MOTION OF THE TRANSLATIONAL DEGREES OF
18. C***** FREEDOM IS NORMAL TO THE SURFACE LET THE MODE ASSUME THE SIGN
19. C***** OF THE LARGEST TOTAL DEFLECTION OVER THE FIRST MODE. ONLY THE
20. C***** F.E. NODES ASSOCIATED WITH THE SURFACE ARE CONSIDERED.
21. A=0.0
22. B=0.0
23. C=0.0
24. DO 30 L=1,NFEN
25. J=IFEN(L)
26. A=A+SN(J,1,1)**2
27. B=B+SN(J,2,1)**2
28. C=C+SN(J,3,1)**2
29. 30 CONTINUE
30. D=AMAX1(A,B,C)
31. IF(A.EQ.0)IB=1
32. IF(B.EQ.0)IB=2
33. IF(C.EQ.0)IB=3
34. SGN=1.0
35. DO 40 K=1,NSM
36. DO 40 L=1,NFEN
37. J=IFEN(L)
38. SGN=SIGN(SGN,SN(J,IB,K))
39. 40 SN(J,1,K)=(SN(J,1,K)**2+SN(J,2,K)**2+SN(J,3,K)**2)**.5*SGN
40. C**** RENORMALIZE THE MODE SHAPE TO GEN-MASS=1.0
41. DO 70 K=1,NSM
42. GM=0.0
43. DO 50 L=1,NFEN
44. J=IFEN(L)
45. 50 GM=VM(J)*SN(J,1,K)**2+GM
46. GM=GM**.5
47. DO 60 L=1,NFEN
48. J=IFEN(L)
49. 60 SN(J,1,K)=SN(J,1,K)/GM
50. 70 CONTINUE
51. C*** TRANSLATE THE F.E. GLOBAL COORDINATES TO THE SURFACE COMPONENT
52. C*** COORDINATE SYSTEM
53. DO 80 I=1,NFEN
54. J=IFEN(I)
55. Xp=D1(J)-SORG(1,IS)

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56.      YP=D2(J)-SORG(2,IS)
57.      ZP=D3(J)-SORG(3,IS)
58.      D1(J)=STM(1,1,IS)*XP+STM(1,2,IS)*YP+STM(1,3,IS)*ZP
59.      D2(J)=STM(2,1,IS)*XP+STM(2,2,IS)*YP+STM(2,3,IS)*ZP
60.      D3(J)=STM(3,1,IS)*XP+STM(3,2,IS)*YP+STM(3,3,IS)*ZP
61.      80 CONTINUE
62.      C SHORT METHOD OF BPQ CALCULATION *****
63.      IF (MOP(4).NE.1) GO TO 1000
64.      DO 200 K=1,NSM
65.      DO 200 M=1,MX
66.      DO 200 N=1,NX
67.      BPQ(M,N,K)=0.0
68.      DO 100 KK=1,NFEN
69.      100 BPQ(M,N,K)=BPQ(M,N,K)+SN(KK,1,K)*SIN(M*PI*D1(KK)/SL1)
70.      !*SIN(N*PI*D2(KK)/SL2)*4/SL1/SL2
71.      200 CONTINUE
72.      GOTO 1111
73.      C END SHORT METHOD *****
74.      C**** LONG METHOD OF BPQ CALCULATION THAT USES INTERPOLATION
75.      C**** BETWEEN DATA POINTS IN CONJUNCTION WITH GAUSSIAN
76.      C**** QUADRATURE
77.      C*** SELECT THE STM MATRIX SUCH THAT THE Z-COMPONENT OF THE
78.      C*** SURFACE COORDINATE SYSTEM IS THE DIRECTION MOST NORMAL
79.      C*** TO THE SURFACE
80.      1000 CONTINUE
81.      DO 1010 I=1,NFEN
82.      TK(I)=I*1.0
83.      1010 CONTINUE
84.      CALL ARASSL( NFES,D1,D2,TK)
85.      K=1
86.      X1(1)=D1(1)
87.      DO 1030 M=1, NFES
88.      IF (D1(M).EQ.X1(K)) GO TO 1030
89.      K=K+1
90.      X1(K)=D1(M)
91.      1030 CONTINUE
92.      K1=K
93.      CALL ARASSL( NFES,D2,D1,TK)
94.      K=1
95.      X2(1)=D2(1)
96.      DO 1040 M=1,NFES
97.      IF (D2(M).EQ.X2(K)) GO TO 1040
98.      K=K+1
99.      X1(K)=D2(M)
100.     1040 CONTINUE
101.     K2=K
102.     DO 1500 MWM=1,NSM
103.     C**** ZERO Y ARRAY
104.     DO 1042 I=1,MMAX
105.     DO 1042 J=1,NMAX
106.     1042 Y(I,J)=0.0
107.     C**** LOAD THE MODE SHAPE TABLE Y
108.     DO 1050 I=1,K1
109.     DO 1050 J=1,K2
110.     DO 1045 K=1,NFEN
111.     1045 IF (D1(K).EQ.D1(I).AND.D2(K).EQ.D2(J))Y(I,J)=SN(INT(TK(K)),1,MWM)
112.     1050 CONTINUE

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113.      CALL BSUR(MWM)
114.      1500 CONTINUE
115.      1111 RETURN
116.      C*****
117.      SUBROUTINE BSUR(MWM)
118.      DIMENSION X8(8),A(8)
119.      DIMENSION DX(8),DA(8)
120.      DO 1070 M=1,MX
121.      DO 1060 N=1,NX
122.      NGP=8
123.      NGP1=NGP/2
124.      CALL GLO(DA,DX,-1.0,1.0,NGP,NGP1)
125.      DO 2 I=1,NGP
126.      XX=DX(I)
127.      AB=DA(I)
128.      X8(I)=XX
129.      2  A(I)=AB
130.      AA=0.0
131.      BB=SL1
132.      H1=(BB-AA)/2.
133.      G1=(BB+AA)/2.
134.      Q1=0.
135.      DO 4 I=1,NGP
136.      UI=H1*X8(I)+G1
137.      AI=H1*A(I)
138.      C=0.0
139.      D=SL2
140.      H=(D-C)/2.
141.      G=(D+C)/2.
142.      Q=0.
143.      DO 3 J=1,NGP
144.      VJ=H*X8(J)+G
145.      3  Q=Q+A(J)*F(UI,VJ)
146.      4  Q1=Q1+AI*H*Q
147.      BPQ(M,N,MWM)=Q1
148.      1060 CONTINUE
149.      1070 CONTINUE
150.      1111 RETURN
151.      C*****
152.      SUBROUTINE GLO(DA,DX,C,D,NGP,NGP1)
153.      DIMENSION DX(NGP),DA(NGP),XX(8),A1(8)
154.      DATA (XX(I),A1(I), I=1,4)/
155.      & .9602898564,.1012285362
156.      &,.7966664774,.2223810344
157.      &,.5255324099,.3137066458
158.      &,.1834346424,.3626837833/
159.      DMC=0.500*(D-C)
160.      DPC=0.500*(D+C)
161.      DO 2 I=1,NGP1
162.      NI=(NGP+1)-I
163.      DX(I)=-DMC*XX(I)+DPC
164.      DX(NI)=DMC*XX(I)+DPC
165.      DA(I)=DMC*A1(I)
166.      2  DA(NI)=DMC*A1(I)
167.      RETURN
168.      FUNCTION F(UI,VJ)
169.      CALL BIVLAG(UI,K1,VJ,K2,X1,3,X2,3,Y,GG,DX1,DX2,1,1,IERR)

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170.      F=4/AREA(IS)*GG*SIN(M*PI*UI/SL1)*SIN(N*PI*VJ/SL2)
171.      RETURN
172.      C*****
173.      SUBROUTINE BIVLAG(A1,M,A2,N,X1,IP1,X2,IP2,Y,G,
174.      1DX1,DX2,MZ1,MZ2,IER)
175.      C*****
176.      C      A1 = FIRST ARGUMENT
177.      C      M  = NUMBER OF POINTS IN X1 TABLE
178.      C      A2 = SECOND ARGUMENT
179.      C      N  = NUMBER OF POINTS IN X2 TABLE
180.      C      X1 = ARRAY OF X1 VALUES
181.      C      IP1= NUMBER OF POINTS TO USE FOR INTERPOLATION FOR A1
182.      C      X2 = ARRAY OF X2 VALUES
183.      C      IP2= NUMBER OF POINTS TO USE FOR INTERPOLATING FOR A2
184.      C      Y  = DEPENDENT VARIABLE TABLE
185.      C      G  = INTERPOLATED VALUE
186.      C      DX1= PARTIAL DERIVATIVE OF Y WITH RESPECT TO X1
187.      C      DX2= PARTIAL DERIVATIVE OF Y WITH RESPECT TO X2
188.      C      MZ1= -1, DX1 WILL BE COMPUTED
189.      C              = +1, DX1 WILL NOT BE COMPUTED
190.      C      MZ2= -1, DX2 WILL BE COMPUTED
191.      C              = +1, DX2 WILL NOT BE COMPUTED
192.      C
193.      C      IER= ERROR FLAG ..0 NO ERROR;  NON-ZERO ERROR
194.      C
195.      DIMENSION X1(M),X2(N),Y(N,M),C(20),D(20),DXN(20),DX1N(20)
196.      G=0.
197.      DX1=0.
198.      DX2=0.
199.      IER=1
200.      IF(IP1 .GT. 20) GO TO 500
201.      IER=3
202.      IF(IP1 .GT. M) GO TO 500
203.      IF(IP2 .GT. 20) GO TO 500
204.      IER=2
205.      IER=4
206.      IF(IP2 .GT. N) GO TO 500
207.      IER=0
208.      I=0
209.      20      I=I+1
210.      IF(A1 .LT. X1(I)) GO TO 30
211.      IF(I .LT. M) GO TO 20
212.      25      IE1=M
213.      IS1=M-IP1+1
214.      GO TO 50
215.      30      IS1=I-IP1/2
216.      IF(IS1 .LT. 1) IS1=1
217.      IE1=IS1+IP1-1
218.      IF(IE1 .GT. M) GO TO 25
219.      50      I=0
220.      60      I=I+1
221.      IF(A2 .LT. X2(I)) GO TO 70
222.      IF(I .LT. N) GO TO 60
223.      65      IE2=N
224.      IS2=N-IP2+1
225.      GO TO 100
226.      70      IS2=I-IP2/2

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227.      IF (IS2 .LT. 1) IS2=1
228.      IE2=IS2+IP2-1
229.      IF (IE2 .GT. N) GO TO 65
230.      100  CONTINUE
231.      IT=IS2
232.      DO 120 I=1,IP2
233.      TN=1.
234.      TD=1.
235.      DO 110 J=IS2,IE2
236.      IF (J .EQ. IT) GO TO 110
237.      TN=TN*(A2-X2(J))
238.      TD=TD*(X2(IT)-X2(J))
239.      110  CONTINUE
240.      C(I)=TN/TD
241.      120  IT=IT+1
242.      IF (M22 .GT. 0) GO TO 200
243.      IT=IS2
244.      DO 150 I=1,IP2
245.      DXN(I)=0.
246.      TD=1.
247.      DO 140 J=IS2,IE2
248.      IF (J .EQ. IT) GO TO 140
249.      TN=1.
250.      DO 130 K=IS2,IE2
251.      IF (K .EQ. J) GO TO 130
252.      IF (K .EQ. IT) GO TO 130
253.      TN=TN*(A2-X2(K))
254.      130  CONTINUE
255.      DXN(I)=DXN(I)+TN
256.      TD=TD*(X2(IT)-X2(J))
257.      140  CONTINUE
258.      DXN(I)=DXN(I)/TD
259.      150  IT=IT+1
260.      200  IT=IS1
261.      DO 220 I=1,IP1
262.      TN=1.
263.      TD=1.
264.      DO 210 J=IS1,IE1
265.      IF (J .EQ. IT) GO TO 210
266.      TN=TN*(A1-X1(J))
267.      TD=TD*(X1(IT)-X1(J))
268.      210  CONTINUE
269.      D(I)=TN/TD
270.      220  IT=IT+1
271.      IF (M21 .GT. 0) GO TO 300
272.      IT=IS1
273.      DO 250 I=1,IP1
274.      DXIN(I)=0.
275.      TD=1.
276.      DO 240 J=IS1,IE1
277.      IF (J .EQ. IT) GO TO 240
278.      TN=1.
279.      DO 230 K=IS1,IE1
280.      IF (K .EQ. IT) GO TO 230
281.      IF (K .EQ. J) GO TO 230
282.      TN=TN*(A1-X1(K))
283.      230  CONTINUE

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284.      DX1N(I)=DX1N(I)+TN
285.      TD=TD*(X1(IT)-X1(J))
286.      240  CONTINUE
287.      DX1N(I)=DX1N(I)/TD
288.      250  IT=IT+1
289.      300  CONTINUE
290.      G=0.
291.      L=IS1
292.      DO 320 I=1,IP1
293.      T=0.
294.      K=IS2
295.      DO 310 J=1,IP2
296.      T=T+C(J)*Y(K,L)
297.      K=K+1
298.      310  CONTINUE
299.      G=G+O(I)*T
300.      L=L+1
301.      320  CONTINUE
302.      350  IF(MZ2 .GT. 0) GO TO 400
303.      DX2=0
304.      K=IS2
305.      DO 380 J=1,IP2
306.      T=0.
307.      L=IS1
308.      DO 370 I=1,IP1
309.      T=T+D(I)*Y(K,L)
310.      L=L+1
311.      370  CONTINUE
312.      DX2=DX2+DXN(J)*T
313.      K=K+1
314.      380  CONTINUE
315.      400  IF(MZ1 .GT. 0) GO TO 500
316.      DX1=0.
317.      L=IS1
318.      DO 420 I=1,IP1
319.      T=0.
320.      K=IS2
321.      DO 410 J=1,IP2
322.      T=T+C(J)*Y(K,L)
323.      K=K+1
324.      410  CONTINUE
325.      DX1=DX1+DX1N(I)*T
326.      L=L+1
327.      420  CONTINUE
328.      NFEDS=NFEDS
329.      ISTYP(1)=ISTYP(1)
330.      L12=L12
331.      500  RETURN
332.      END
```

FTN 1752 IBANK 640 DBANK

,S XX,FRQCAL,XX.

1CR1A 12/14/83-18:38(44,)

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1. C*****
2. SUBROUTINE FRQCAL(WN,WMO,WM,W1,W2,W3,W4,NM,IPRE,VNODC,ONODC,SNODC,
3. ECENTF,NSDAT,NSTOR,IVTYP,IOTYP,ISTYP,SC,IFE,
4. *NAM,NV,NMO,NOO,NSMX,NMS,NS,MXV,MXS,MBAND,
5. *CO,PI,NFS,NTOB,NSC,IOP,L8,L9,MXM,LN)
6. C*
7. C*
8. C* FRQCAL DIRECTS CALCULATION OF VOLUME,OPENING,AND STRUCTURAL
9. C* NATURAL FREQUENCIES.
10. C*
11. COMMON/AREA9/FAC,PSI,DPI,DN,UP
12. DOUBLE PRECISION FAC(57),PSI(60),DPI,DN,UP
13. DIMENSION WN(4,NAM,NV),WMO(3,NMO,NOO),WM(3,NSMX),
14. *NM(NMS),IPRE(4),VNODC(MXV,3,NV),ONODC(MXS,3,NOO)
15. *,SNODC(MXS,3,NS),CENTF(NTOB),NSDAT(NS),NSTOR(NS),IVTYP(NV),
16. *IOTYP(NOO),SC(NSC,NS),ISTYP(NS),IFE(NMS)
17. DIMENSION W1(MXM),W2(MXM),W3(MXM),W4(MXM)
18. INTEGER S
19. FAL=1.5*CENTF(MBAND)
20. FSL=FAL
21. IF(LN.EQ.1) THEN
22. MMAX=0
23. NMAX=0
24. ISMAX=0
25. C**** ESTIMATE THE MAXIMUM MODE NUMBER NEEDED
26. CALL MODEST(MXM,MMAX,NMAX,ISMAX,MSX,NSX)
27. RETURN
28. ELSE
29. ENDIF
30. NFS=NFS
31. C**** IF REQUIRED, CALCULATE ACOUSTIC MODES
32. IF(IPRE(1).EQ.1) GOTO 250
33. WRITE(6,*)MXM,MMAX,NMAX,ISMAX
34. DO 110 NVOL=1,NV
35. NWN=0
36. DO 80 N=0,NMAX
37. DO 70 M=0,MMAX
38. DO 60 S=0,ISMAX
39. WT=OMEGA(NVOL,M,N,S)
40. IF(NWN.GE.MXM) GOTO 90
41. IF(WT.GT.FAL.AND.NWN.GE.NAM) GOTO 70
42. IF(WT.EQ.-1.0) GOTO 70
43. NWN=NWN+1
44. W1(NWN)=WT
45. W2(NWN)=M*1.0
46. W3(NWN)=N*1.0
47. W4(NWN)=S*1.0
48. 60 CONTINUE
49. 70 CONTINUE
50. 80 CONTINUE
51. 90 CONTINUE
52. C**** SORT ACOUSTIC MODES
53. CALL ARLSSL(NWN,W1,W2,W3,W4)
54. DO 100 I=1,NAM
55. WN(1,I,NVOL)=W1(I)

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56.      WN(2,I,NVOL)=W2(I)
57.      WN(3,I,NVOL)=W3(I)
58.      WN(4,I,NVOL)=W4(I)
59.      100 CONTINUE
60.      110 CONTINUE
61.      WRITE(6,*)WN
62.      C****    CALCULATE OPENING ALLOWED FREQUENCY CONSTANTS
63.      IF(NV.EQ.1)GOTO 250
64.      DO 200 IS=1,N00
65.      MWM=0
66.      DO 180 N=0,NMAX
67.      DO 170 M=0,MMAX
68.      WT=OMEGA0(IS,M,N)
69.      IF(WT.EQ.-1.0) GOTO 170
70.      MWM=MWM+1
71.      W1(MWM)=WT
72.      W2(MWM)=M*1.0
73.      W3(MWM)=N*1.0
74.      170 CONTINUE
75.      180 CONTINUE
76.      C****    SORT OPENING MODES
77.      CALL ARLSSL(MWM,W1,W2,W3,W4)
78.      DO 195 I=1,NM0
79.      WMO(1,I,IS)=W1(I)
80.      WMO(2,I,IS)=W2(I)
81.      WMO(3,I,IS)=W3(I)
82.      195 CONTINUE
83.      200 CONTINUE
84.      WRITE(6,*)MSX,NSX
85.      WRITE(6,*)WMO
86.      C****    CALCULATE THE FIRST NSMX STRUCTURAL NATURAL FREQUENCIES
87.      C****    THAT ARE LESS THAN FAL
88.      250 IF(IOP.GE.5)GOTO 1111
89.      DO 310 IS=1,NMS
90.      MWM=0
91.      IF(NSDAT(IS).NE.0) GOTO 310
92.      IF(IFE(IS).NE.0) GOTO 310
93.      IF(ISTYP(IS).EQ.0)GOTO 310
94.      IF(ISTYP(IS).EQ.7)GOTO 310
95.      DO 280 N=1,NSX
96.      DO 270 M=1,MSX
97.      WT=OMEGAM(IS,M,N)
98.      WRITE(6,*)M,N,WT,MMAX,MXM
99.      IF(MWM.GE.MXM) GOTO 290
100.     IF(WT.GT.FSL.AND.MWM.GE.NSMX) GOTO 270
101.     MWM=MWM+1
102.     W1(MWM)=WT
103.     W2(MWM)=M*1.0
104.     W3(MWM)=N*1.0
105.     W4(MWM)=N*1.0
106.     270 CONTINUE
107.     280 CONTINUE
108.     290 CONTINUE
109.     C****    SORT STRUCTURAL NATURAL FREQUENCIES
110.     CALL ARLSSL(MWM,W1,W2,W3,W4)
111.     DO 293 I=1,MWM
112.     293 IF(W1(I).GT.FSL)GOTO 294

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113.      294 NM(IS)=I-1
114.          IF(NM(IS).GT.NSMX)NM(IS)=NSMX
115.          DO 295 I=1,NSMX
116.              WM(1,I)=W1(I)
117.              WM(2,I)=W2(I)
118.              WM(3,I)=W3(I)
119.      295 CONTINUE
120.          IR=NSTOR(IS)
121.          WRITE(L9*IR) WM
122.      310 CONTINUE
123.          DO 320 IS=1,NMS
124.              IF(NSDAT(IS).NE.0)GOTO 320
125.              IR=NSTOR(IS)
126.              WRITE(L8*IR)NM(IS)
127.      320 CONTINUE
128.          DO 330 IS=1,NMS
129.              IF(NSDAT(IS).EQ.0)GOTO 330
130.              IR=NSDAT(IS)
131.              READ(L8*IR)NM(IS)
132.      330 CONTINUE
133.          WRITE(6,*)FAL,FAL,FAL,FAL
134.          WRITE(6,*)WM
135.          WRITE(6,*)NM
136.      1111 RETURN
137.      C*****
138.          FUNCTION OMEGAN(NVOL,M,N,IS)
139.      C*
140.      C*
141.      C*   CALCULATE THE (M,N,IS) ACOUSTIC NATURAL FREQUENCY OF SUBVOLUME
142.      C*   NVOL.
143.      C*
144.      C*
145.          GOTO(10,20,30,40),IVTYP(NVOL)
146.      C****   VOLUME TYPE #1. RETANGULAR PARALLELEPIPED
147.      10   OMEGAN=CO*PI*((M/VNODC(2,1,NVOL))**2+(N/VNODC(3,2,NVOL))**2+
148.          &(IS/VNODC(4,3,NVOL))**2)**0.5
149.          GOTO 1111
150.      C****   VOLUME TYPE #2. CIRCULAR CYLINDER
151.      20   IF(M.NE.0) GOTO 22
152.          OMEGAN=-1.0
153.      C   INITIALIZATION
154.          RLST=0.0
155.          MLST=M
156.          AKNM=0.0
157.          GOTO 1111
158.      22   IF(MLST.EQ.M) GOTO 26
159.          IF(N.EQ.0.AND.M.EQ.1)GOTO 26
160.          IT=1
161.          CALL ZERO(AKNM,RLST,N,VNODC(2,1,NVOL),VNODC(3,2,NVOL),IT)
162.          MLST=M
163.      26   OMEGAN=CO*((IS*PI/VNODC(4,3,NVOL))**2+AKNM**2)**0.5
164.          GOTO 1111
165.      C****   VOLUME TYPE #3. CONCENTRIC CYLINDERICAL ANNULOUS
166.      30   IF(M.NE.0) GOTO 32
167.          OMEGAN=-1.0
168.      C   INITIALIZATION
169.          RLST=0.0

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170.      MLST=M
171.      AKNM=0.0
172.      GOTO 1111
173.      32 IF (MLST.EQ.M) GOTO 36
174.      IT=2
175.      CALL ZERO(AKNM,RLST,N,VNODC(4,2,NVOL),VNODC(2,1,NVOL),IT)
176.      MLST=M
177.      36 OMEGAN=CO*((IS*PI/VNODC(4,3,NVOL))**2+AKNM**2)**0.5
178.      GOTO 1111
179.      C**** VOLUME TYPE #4.PERTURBED PARALLELEPIPED
180.      40 RLST=PI*((M/VNODC(2,1,NVOL))**2+(N/VNODC(3,2,NVOL))**2+
181.      & (IS/VNODC(4,3,NVOL))**2)**0.5
182.      R=VNODC(5,3,NVOL)-VNODC(4,3,NVOL)
183.      R=R/VNODC(4,3,NVOL)
184.      AKNM=0.0
185.      IF (N.EQ.0.AND.IS.EQ.0)GOTO 41
186.      IF (N.EQ.0) A1=-1./3.
187.      IF (N.NE.0) A1=1./N**2/PI**2
188.      AKNM=(-2.0*(IS*PI/VNODC(4,3,NVOL))**2*(1./3.-A1)-4./
189.      & VNODC(3,2,NVOL)**2)/(N*PI/VNODC(3,2,NVOL))**2+
190.      & (IS*PI/VNODC(4,3,NVOL))**2)
191.      41 CONTINUE
192.      WRITE(6,*)M,N,IS,VNODC(2,1,NVOL),VNODC(3,2,NVOL),
193.      & VNODC(4,3,NVOL),RLST,AKNM
194.      OMEGAN=CO*RLST*(1+2.*R*AKNM*((N*PI/VNODC(3,2,NVOL))**2
195.      & +(IS*PI/VNODC(4,3,NVOL))**2)/RLST**2)**0.5
196.      WRITE(6,*)OMEGAN
197.      GOTO 1111
198.      C****
199.      C****
200.      1111 RETURN
201.      C*****
202.      FUNCTION OMEGA0(IS,M,N)
203.      C*
204.      C*
205.      C* CALCULATE THE (M,N) OPENING ALLOWED FREQUENCY CONSTANTS
206.      C*
207.      C*
208.      GOTO(10,20,30),IOTYP(IS)
209.      C**** OPENING TYPE #1. RETANGULAR
210.      10 OMEGA0=((M/ONODC(2,1,IS))**2+(N/ONODC(3,2,IS))**2)**0.5
211.      GOTO 1111
212.      C**** OPENING TYPE #2. CIRCLE
213.      20 IF (M.NE.0) GOTO 22
214.      OMEGA0=-1.0
215.      C INITIALIZATION
216.      RLST=0.0
217.      MLST=M
218.      AKNM=0.0
219.      GOTO 1111
220.      22 IF (MLST.EQ.M) GOTO 26
221.      IF (N.EQ.0.AND.M.EQ.1)GOTO 26
222.      IT=1
223.      CALL ZERO(AKNM,RLST,N,ONODC(2,1,IS),ONODC(3,2,IS),IT)
224.      MLST=M
225.      26 OMEGA0=AKNM
226.      GOTO 1111

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227. C**** OPENING TYPE #3. CONCENTRIC CIRCLE
228. 30 IF(M.NE.0) GOTO 32
229. OMEGA0=-1.0
230. C INITIALIZATION
231. RLST=0.0
232. MLST=M
233. AKNM=0.0
234. GOTO 1111
235. 32 IF(MLST.EQ.M) GOTO 36
236. IT=2
237. CALL ZERO(AKNM,RLST,N,ONODC(3,2,IS),ONODC(2,1,IS),IT)
238. MLST=M
239. 36 OMEGA0=AKNM
240. GOTO 1111
241. C****
242. 1111 RETURN
243. C*****
244. FUNCTION OMEGAM(IS,M,N)
245. C*
246. C*
247. C* CALCULATE STRUCTURAL NATURAL FREQUENCIES
248. C*
249. C*
250. DIMENSION CF(4,11),AM(3,3),VK(3,3),VM(3,3),C(3,3),EWC(3,3),EVR(3)
251. & ,EVI(3)
252. WRITE(6,*)IS,M,N,ISTYP(IS),SC(1,IS)
253. GOTO(10,20,30,40,50,60,70,80),ISTYP(IS)
254. C**** SURFACE TYPE #1. RETANGULAR SHAPE WITH FOURIER SERIES MODE SHAPE
255. 10 CONTINUE
256. C NORMALLY PROVIDED AS DATA
257. GOTO 1111
258. C**** SURFACE TYPE #2. ORTHOTROPIC RETANGULAR PANEL WITH SIMPLY
259. C**** SUPPORTED EDGES
260. 20 CONTINUE
261. G1=M*1.
262. G2=N*1.
263. H1=G1**2
264. H2=G2**2
265. DXY=SC(1,IS)*SC(5,IS)+2.*SC(3,IS)
266. OMEGAM=PI**2/SC(6,IS)**0.5*(G1**4*SC(1,IS)/SNODC(2,1,IS)**4
267. &+ G2**4*SC(2,IS)/SNODC(3,2,IS)**4+2.*H1*H2*DXY/(SNODC(2,1,IS)**2
268. & * SNODC(3,2,IS)**2)**0.5
269. GOTO 1111
270. C**** SURFACE TYPE #3. CIRCULAR SHAPE WITH FOURIER SERIES MODE SHAPES
271. 30 CONTINUE
272. C NORMALLY PROVIDED AS DATA
273. GOTO 1111
274. C**** SURFACE TYPE #4. THIN,HOMOGENEOUS CIRCULAR PANEL WITH FIXED
275. C**** EDGES
276. 40 CONTINUE
277. DATA((CF(J,I),I=1,11),J=1,4)/1.017,2.007,3.005,4.003,1.468,
278. &2.483,3.488,4.491,1.8,2.927,3.948,4.959,2.274,3.354,4.391,
279. &5.413,2.657,3.768,4.822,5.856,3.032,4.172,5.244,6.289,3.402,
280. &4.569,5.658,6.715,3.767,4.961,6.066,7.135,4.129,5.347,6.469,
281. &7.549,4.488,5.73,6.867,7.959,6.109,6.5,7.261,8.365/
282. IF(N.LE.11.AND.M.LE.4)BETA=CF(M,N)
283. IF(N.GT.11.OR.M.GT.4) BETA=M*(N-1)/2.

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284.      OMEGAM=SC(1,IS)*BETA**2
285.      GOTO 1111
286.      C**** SURFACE TYPE #5. FRAME STIFFENED CYLINDRICAL WHOLE SHELL
287.      50 CONTINUE
288.      AL=2*PI
289.      51 B=SNODC(3,2,IS)
290.      PBX=(M*PI*SNODC(3,2,IS)/SNODC(2,1,IS))
291.      QPA=((N-1)*PI/AL)
292.      VK(1,1)=SC(1,IS)/SC(2,IS)*(PBX**2+(1-SC(5,IS))/2*QPA**2)
293.      VK(2,2)=((1+SC(5,IS))/2.0*SC(1,IS)/SC(2,IS)*PBX**2+QPA**2)
294.      VK(3,3)=1+SC(4,IS)/B**2/SC(4,IS)*(SC(3,IS)/SC(4,IS)*
295.      & PBX**4+2*SC(3,IS)/SC(4,IS)*PBX**2*QPA**2+QPA**4)
296.      VK(2,1)=((1+SC(5,IS))/2.0*SC(1,IS)/SC(2,IS)*PBX*QPA
297.      VK(1,2)=VK(2,1)
298.      VK(1,3)=SC(5,IS)*SC(1,IS)/SC(2,IS)*PBX
299.      VK(3,1)=VK(1,3)
300.      VK(2,3)=QPA
301.      VK(3,2)=VK(2,3)
302.      DO 52 I=1,3
303.      DO 52 J=1,3
304.      52 VM(I,J)=0.0
305.      VM(1,1)=SC(6,IS)*B**2/SC(2,IS)
306.      VM(2,2)=VM(1,1)
307.      VM(3,3)=VM(1,1)
308.      CALL GASINV(VM,3,DET)
309.      CALL MTXMPY(VK,VM,C,3,3)
310.      CALL EIGEN(C,AM,EWC,EVR,EVI,3,3,3,0)
311.      OMEGAM=EVR(3)
312.      GOTO 1111
313.      C**** SURFACE TYPE #6. FRAME STIFFENED CYLINDRICAL SHELL SEGMENT
314.      60 AL=ATAN(SNODC(4,3,IS)/SNODC(4,2,IS))
315.      GOTO 51
316.      C***
317.      C**** SURFACE TYPE #7. BBN F.E. DATA MODEL
318.      70 GOTO 1111
319.      C**** SURFACE TYPE #8. ORTHOTROPIC RECTANGULAR PANEL WITH CLAMPED EDGES
320.      80 G1= M + 0.5
321.      G2= N + 0.5
322.      H1=G1**2*(1.0-2./(G1*PI))
323.      H2=G2**2*(1.0-2./(G2*PI))
324.      IF(M.EQ.1)H1=1.248
325.      IF(N.EQ.1)H2=1.248
326.      DXY=SC(1,IS)*SC(5,IS)+2.*SC(3,IS)
327.      OMEGAM=PI**2/SC(6,IS)**0.5*(G1**4*SC(1,IS)/SNODC(2,1,IS)**4
328.      & G2**4*SC(2,IS)/SNODC(3,2,IS)**4+2.*H1*H2*DXY/(SNODC(2,1,IS)**2
329.      & * SNODC(3,2,IS)**2)**0.5
330.      GOTO 1111
331.      C****
332.      1111 RETURN
333.      C*****
334.      SUBROUTINE ZERO(AKNM,RLST,N,A,B,IT)
335.      C*
336.      C* FIND THE NEXT ZERO OF THE EQUATION ,IT, AS HELD IN THE
337.      C* ROUTINE EQ
338.      STEP=.1
339.      XO=RLST+STEP
340.      X=XO

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341.      CALL EQ(DETO,X0,N,A,B,IT)
342.      ER=0.01
343.      NI=10
344.      15 CONTINUE
345.      X=X+STEP
346.      CALL EQ(DET,X,N,A,B,IT)
347.      WRITE(6,*)X0,DETO,X,DET
348.      IF(DETO.LT.0.0.AND.DET.LT.0.0)GO TO 20
349.      IF(DETO.GT.0.0.AND.DET.GT.0.0)GO TO 20
350.      FIRST=X0
351.      RAST=X
352.      GO TO 30
353.      20 X0=X
354.      DETO=DET
355.      GO TO 15
356.      C***** NEWTON RAPHSON ITERATION *****
357.      30 XX0=FIRST
358.      YRLST=DETO
359.      XXN=RAST
360.      YDETN=DET
361.      NIT=0
362.      YMAX=AMAX1(ABS(YRLST),ABS(YDETN))
363.      40 EPS=ABS(YDETN/YMAX)
364.      NIT=NIT + 1
365.      IF(EPS.LE.ER)GO TO 50
366.      IF(NIT.GT.NI) GO TO 50
367.      X1=XXN- XX0
368.      Y1=YDETN- YRLST
369.      XY1= X1/Y1
370.      X=XXN-YDETN * XY1
371.      CALL EQ(DET,X,N,A,B,IT)
372.      WRITE(6,*)X,DET,EPS
373.      S=SIGN(1.0,DET)
374.      S1=SIGN(1.0,YDETN)
375.      IF(S.EQ.S1.AND.ABS(DET).GT.ABS(YDETN)) GOTO 45
376.      XX0=XXN
377.      YRLST=YDETN
378.      XXN=X
379.      YDETN=DET
380.      GO TO 40
381.      45 XXN=X
382.      YDETN=DET
383.      GOTO 40
384.      C*
385.      50 RLST=X
386.      AKNM=X*PI/A
387.      1111 RETURN
388.      *C*****
389.      SUBROUTINE EQ(DET,X,N,A,B,IT)
390.      C*
391.      C* CALCULATE THE VALUE OF A FUNCTION. THE FUNCTION IS USED
392.      C* TO ESTABLISH ALLOWED FREQUENCY CONSTANTS FOR VOLUMES,OPENINGS,
393.      C* AND SURFACES
394.      C*
395.      GOTO(10,20),IT
396.      C**** CIRCLE OR CIRCULAR CYLINDER
397.      10 XA=X*PI

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398.      DET=BJP(XA,N)
399.      GOTO 1111
400.      C****
401.      C**** CONCENTRIC CIRCULAR ANNULOUS
402.      20 XA=X*PI
403.      XB=X*B/A
404.      DET=BJP(XA,N)*BYP(XB,N)-BJP(XB,N)*BYP(XA,N)
405.      GOTO 1111
406.      1111 RETURN
407.      C*********
408.      FUNCTION BJ(X,N)
409.      C      COMPUTES THE J BESSEL FUNCTION OF THE FIRST KIND FOR A
410.      C      GIVEN ARGUMENT X, AND A GIVEN ORDER N.
411.      C      X=ARGUMENT OF THE J BESSEL FUNCTION
412.      C      N=THE ORDER OF THE J BESSEL FUNCTION
413.      C      D=REQUIRED ACCURACY
414.      C      BJ=THE RESULTANT BESSEL FUNCTION
415.      C      DOUBLE PRECISION XD,Z,ZZ,VAR,VAL,SUM,TOTAL,BLJ
416.      C      DEFINE BSLJ(TOTP,TOTQ,ARG)=SQRT(2./(PI*X))*
417.      C      (TOTP*SIN(ARG)+TOTQ*COS(ARG))
418.      C      XD=DBLE(X)
419.      C      IF(X.GT.10.)GOTO 250
420.      C      IF(N.GT.55) GOTO 300
421.      C      IF(X.EQ.0.) GOTO 30
422.      C      M1=57-N
423.      C      Z=1.000
424.      C      ZZ=XD*XD
425.      C      SUM=0.000
426.      C      TOTAL=0.000
427.      C      BJ1=1.000
428.      C      DO 10 I=1,M1
429.      C      K=I-1
430.      C      VAR=2.00**(2*K+N)
431.      C      TOTAL=SUM+BJ1*Z/FAC(I)/FAC(I+N)/VAR
432.      C      IF(TOTAL.EQ.0.00)GOTO 5
433.      C      VAL=SUM/TOTAL
434.      C      IF(VAL.GT.DN.AND.VAL.LT.UP) GOTO 20
435.      C      5 BJ1=-BJ1
436.      C      Z=Z*ZZ
437.      C      SUM=TOTAL
438.      C      10 CONTINUE
439.      C      20 BLJ=XD**N*TOTAL
440.      C      BJ=REAL(BLJ)
441.      C      RETURN
442.      C      30 IF(N.GT.0) GOTO 40
443.      C      BJ=1.0
444.      C      RETURN
445.      C      40 BJ=0.0
446.      C      RETURN
447.      C**** USE ASYMTOTIC SERIES SOLUTION
448.      C      250 IF(N.GT.8) GOTO 275
449.      C      CALL PSQS(N,X,TOTP,TOTQ,ARG)
450.      C      BJ=BSLJ(TOTP,TOTQ,ARG)
451.      C      RETURN
452.      C**** USE ASYMTOTIC SERIES THE RECURSION WHEN N>8
453.      C      275 CALL PSQS(8,X,TOTP,TOTQ,ARG)
454.      C      BLJN=BSLJ(TOTP,TOTQ,ARG)

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455.      CALL PSQS(7,X,TOTP,TOTQ,ARG)
456.      BLJNM1=BSLJ(TOTP,TOTQ,ARG)
457.      CALL RECURIN,X,BLJN,BLJNM1,BJ)
458.      RETURN
459.      300 BJ=0.0
460.      RETURN
461.      C*****
462.      C*****
463.      FUNCTION BY(X,N)
464.      C*
465.      C* CALCULATES THE NEUMANN FUNCTION
466.      C*
467.      DOUBLE PRECISION XD,TOTAL,CUM,SUM,Z,ZZ,DIV,VAL,BLY,BLJ
468.      DEFINE BSLY(TOTP,TOTQ,ARG)=SQRT(2./(PI*X))*
469.      & (TOTP*SIN(ARG)+TOTQ*COS(ARG))
470.      XD=DBLE(X)
471.      IF(X.GT.10.)GOTO 250
472.      IF(N.GT.55) GOTO 300
473.      C*** CALCULATE BY SERIES DEFINITION
474.      IF(X.EQ.0.)GOTO 50
475.      TOTAL=0.00
476.      CUM=0.00
477.      SUM=0.00
478.      Z=XD*XD/4.00
479.      IF(N.EQ.0) GOTO 15
480.      ZZ=1.00
481.      DO 10 I=1,N
482.      DIV=FAC(N-I+1)/FAC(I)
483.      CUM=CUM+DIV*ZZ
484.      ZZ=ZZ*Z
485.      10 CONTINUE
486.      15 ZZ=1.00
487.      BY1=1.00
488.      M1=57-N
489.      DO 30 I=1,M1
490.      DIV=ZZ/FAC(I)
491.      TOTAL=SUM+(PSI(I)+PSI(I+N))*BY1*DIV/FAC(I+N)
492.      VAL=SUM/TOTAL
493.      IF(VAL.GT.DN.AND.VAL.LT.UP) GOTO 40
494.      20 BY1=-BY1
495.      ZZ=ZZ*Z
496.      SUM=TOTAL
497.      30 CONTINUE
498.      40 DIV=((2.00/XD)**N)/DPI
499.      BLJ=DBLE(BJ(X,N))
500.      BLY=(-DIV)*CUM+(2.00/DPI)*DLOG(XD/2.00)*BLJ-(((XD/2.00)**N)/PI)
501.      & * TOTAL
502.      BY=PEAL(BLY)
503.      RETURN
504.      50 BY=-1.0E35
505.      RETURN
506.      60 BY=1.0E35
507.      RETURN
508.      C**** USE ASYMTOTIC SERIES SOLUTION
509.      250 IF(N.GT.8) GOTO 275
510.      CALL PSQS(N,X,TOTP,TOTQ,ARG)
511.      BY=BSLY(TOTP,TOTQ,ARG)

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512.      RETURN
513.      C**** USE ASYMTOTIC SERIES THEN RECURSION FOR N>8
514.      275 CALL PSQS(8,X,TOTP,TOTQ,ARG)
515.      BLYN=BSLY(TOTP,TOTQ,ARG)
516.      CALL PSQS(7,X,TOTP,TOTQ,ARG)
517.      BLYN1=BSLY(TOTP,TOTQ,ARG)
518.      CALL RECUR(N,X,BLYN,BLYNM1,BY)
519.      RETURN
520.      300 BY=-1.35
521.      RETURN
522.      C*****
523.      SUBROUTINE PSQS(N,X,TOTP,TOTQ,ARG)
524.      DOUBLE PRECISION ATEX,BJ1,TRMP,TRMQ,SUMP,SUMQ,RJ,RK,U,VAL,TP,TQ,XC
525.      XD=DBLE(X)
526.      U=4.0D*N*N
527.      ATEX=8.0D*X
528.      BJ1=-1.0D
529.      TRMP=1.0D
530.      SUMP=1.0D0
531.      SUMQ=0.0D
532.      RJ=1.0D
533.      DO 10 M=2,56,2
534.      RK=RJ+2.0D
535.      TRMQ=TRMP*(U-RJ*RJ)/ATEX
536.      TRMP=TRMQ*(U-RK*RK)/ATEX
537.      TP=SUMP+BJ1*TRMP/FAC(M+1)
538.      BJ1=-BJ1
539.      TQ=SUMQ+BJ1*TRMQ/FAC(M)
540.      IF(TQ.EQ.0.0D)GOTO 5
541.      VAL=SUMQ/TQ
542.      IF(VAL.GT.DN.AND.VAL.LT.UP) GOTO 20
543.      5 SUMQ=TQ
544.      SUMP=TP
545.      RJ=RK+2.0D
546.      10 CONTINUE
547.      20 ARG=REAL(X-DPI*(N/2.0D+0.25D))
548.      TOTP=REAL(TP)
549.      TOTQ=REAL(TQ)
550.      RETURN
551.      C*****
552.      SUBROUTINE RECUR(N,X,BSLN,BSLNM1,BSL)
553.      QTNT=2./X
554.      K=N-1
555.      DO 10 I=8,K
556.      BSLNP1=QTNT*I*BSLN-BSLNM1
557.      BSLNM1=BSLN
558.      BSLN=BSLNP1
559.      10 CONTINUE
560.      BSL=BSLN
561.      RETURN
562.      C*****
563.      FUNCTION BI(X,N)
564.      C COMPUTES THE I BESSEL FUNCTION(MODIFIED) FOR A GIVEN ARGUMENT
565.      C AND ORDER.
566.      C X=ARGUMENT OF THE I BESSEL FUNCTION
567.      C N=ORDER OF THE I BESSEL FUNCTION
568.      C BI=RESULTANT

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569.  C      N MUST BE GREATER THAN OR EQUAL TO ZERO
570.  C
571.  C      CHECK FOR ERRORS IN N AND X AND EXIT CONDITIONAL
572.  C
573.      IER=0
574.      BI=1.0
575.      IF(N) 150,15,10
576.  10      IF(X) 160,20,20
577.  15      IF(X) 160,17,20
578.  17      RETURN
579.  C
580.  C      DEFINE TOLERANCE
581.  C
582.  20      TOL=1.E-4
583.  C
584.  C      IF ARGUMENT GT 12 AND GT N, USE ASYMPTOTIC FORM
585.  C
586.      IF(X-12.) 40,40,30
587.  30      IF(X-FLOAT(N)) 40,40,110
588.  C
589.  C      COMPUTE FIRST TERM OF SERIES AND SET INITIAL VALUE OF THE SUM
590.  C
591.  40      XX=X/2.
592.      FACTN=1.0
593.      IF(N-1) 70,70,50
594.  50      DO 60 I=2,N
595.      FI=I
596.  60      FACTN=FACTN*FI
597.  70      TERM=(XX**N)/FACTN
598.      BI=TERM
599.      XX=XX*XX
600.  C
601.  C      COMPUTE UP TO 30 TERMS, STOPPING WHEN ABS(TERM) LE ABS(SUM OF
602.  C      TERM TIMES TOLERANCE
603.  C
604.      DO 90 K=1,30
605.      IF(ABS(TERM)-ABS(BI*TOL)) 100,100,80
606.  80      FK=K*(N+K)
607.      TERM=TERM*(XX/FK)
608.  90      BI=BI+TERM
609.  C
610.  C      RETURN BI AS ANSWER
611.  C
612.  100     RETURN
613.  C
614.  C      X GT 12 AND X GT N, SO USE ASYMPTOTIC APPROXIMATION
615.  C
616.  110     FNT=4*N*N
617.      XX=1./(8.*X)
618.      TERM=1.
619.      BI=1.
620.      DO 130 K=1,30
621.      IF(ABS(TERM)-ABS(TOL*BI)) 140,140,120
622.  120     FK=(2*K-1)**2
623.      TERM=TERM*XX*(FK-FNT)/FLOAT(K)
624.  130     BI=BI+TERM
625.  140     PI=3.141592653

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626.      BI=BI*EXP(X)/SQRT(2.*PI*X)
627.      GO TO 100
628.      150 IER=1
629.      GO TO 100
630.      160 IER=2
631.      GO TO 100
632.      C*****
633.      FUNCTION BJP(X,N)
634.      C*
635.      C* CALCULATE THE DERIVATIVE OF THE BESSEL FUNCTION OF THE FIRST
636.      C* KIND OF ORDER N
637.      C*
638.      IF(N.EQ.0)BJP=-1.0*BJ(X,N+1)
639.      IF(N.GT.0)BJp=0.5*(BJ(X,N-1)-BJ(X,N+1))
640.      1111 RETURN
641.      C*****
642.      FUNCTION BYP(X,N)
643.      C*
644.      C* DERIVATIVE OF THE BESSEL FUNCTION OF THE SECOND KIND OF ORDER N
645.      C*
646.      IF(N.EQ.0)BYP=-1.0*BY(X,N+1)
647.      IF(N.GT.0)BYp=0.5*(BY(X,N-1)-BY(X,N+1))
648.      1111 RETURN
649.      C*****
650.      FUNCTION BIP(X,N)
651.      C*
652.      C* DERIVATIVE OF THE MODIFIED BESSEL FUNCTION OF THE FIRST KIND
653.      IF(N.EQ.0)BIP=-1.0*BI(X,N+1)
654.      IF(N.GT.0)BIP=0.5*(BI(X,N-1)-BI(X,N+1))
655.      RETURN
656.      C*****
657.      SUBROUTINE MODEST(MXM,MMA,X,NMAX,ISMAX,MSX,NSX)
658.      C*
659.      C* ESTIMATE THE MAXIMUM INDICIES FOR FREQUENCY CALCULATIONS
660.      C*
661.      DO 100 NVOL=1,NV
662.      GOTO(10,20,30),IVTYP(NVOL)
663.      C***** VOLUME TYPE #1. RETANGULAR PARALLELEPIPED
664.      10 N=3
665.      S=0
666.      M1=NINT(FAL*VNODC(2,1,NVOL)/CO/PI)
667.      M=0
668.      N=0
669.      IS1=NINT(FAL*VNODC(4,3,NVOL)/CO/PI)
670.      M=0
671.      S=0
672.      N1=NINT(FAL*VNODC(3,2,NVOL)/CO/PI)
673.      IF(M1.GT.MMAX)MMAX=M1
674.      IF(N1.GT.NMAX)NMAX=N1
675.      IF(IS1.GT.ISMAX)ISMAX=IS1
676.      GOTO 100
677.      C***** VOLUME TYPE #2. CIRCULAR CYLINDER
678.      20 CONTINUE
679.      MMAX=7
680.      NMAX=7
681.      ISMAX=7
682.      C***** VOLUME TYPE #3. CONCENTRIC CIRCULAR CYLINDER
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683.      30 CONTINUE
684.      MMAX=7
685.      NMAX=7
686.      ISMAX=7
687.      100 CONTINUE
688.      C**** SCALE MAX MODE RESULTS
689.      DO 150 I=1,MMAX
690.          IF(MMAX*NMAX*ISMAX.LE.4*NAM)GOTO 160
691.          MMAX=MMAX-1
692.          NMAX=NMAX-1
693.          ISMAX=ISMAX-1
694.      150 CONTINUE
695.      160 CONTINUE
696.      C*****
697.      C***** IT IS ASSUMED THAT THE TOTAL NUMBER OF ACOUSTIC MODES
698.      C      MXM> .GE. MSX*MSX OF THE SURFACE. THE MXM IS TO SIZE THE
699.      C      WORKING ARRAYS. CALCULATION OF STURCTURAL AND ACOUSTIC
700.      C      FREQUENCIES ARE LIMITED TO THE FREQUENCIES WITHIN THE RANGE
701.      C      OF INTEREST BY THE INDIVIDUAL CALCULATION ROUTINES.
702.      C*
703.          MXM=MMAX*NMAX*ISMAX
704.      170 IF(MXM.LT.NAM)MMAX=MMAX+1
705.          MXM=MMAX*NMAX*ISMAX
706.          IF(MXM.LT.NAM)NMAX=NMAX+1
707.          MXM=MMAX*NMAX*ISMAX
708.          IF(MXM.LT.NAM)ISMAX=ISMAX+1
709.          MXM=MMAX*NMAX*ISMAX
710.          IF(MXM.LT.NAM)GOTO 170
711.          MSX=(1.*MXM)**.5
712.          IF(MSX**2.LT.MXM)MSX=MSX+1
713.          IF(MSX**2.LT.MXM)MSX=MSX+1
714.          IF(MMAX**2.GT.MXM)MSX=MSX-1
715.          NSX=MSX
716.          RETURN
717.          END

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FTN 3490 IBANK 1395 DBANK 240 COMMON

,S XX.BNDCAL,XX.

10R1A 12/14/83-18:38(29,)

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1.  C****
2.      SUBROUTINE BNDCAL(BNDWN,BNDWM,WNMC,WM,ZM,ZN,NM,CENTF,NSTOR,NS,NTOB
3.      E,NAM,NSMX,NMS,BW,EPS,NFS,IPRE,ISTYP,L8,L9,L15,NSDAT,IOP,NPROB)
4.  C*
5.  C*
6.  C*      BNDCAL CALCULATES THE BANDWIDTH OF IMPORTANT MODES AROUND EACH
7.  C*      BAND OF MODAL ANALYSIS INTEREST
8.  C*
9.  C*
10.     DIMENSION BNDWN(NTOB,2),BNDWM(NTOB,2),WNMC(NAM),WM(3,NSMX),ZM(NSMX
11.     E ),CENTF(NTOB),ZN(NAM),NSTOR(NMS),NM(NMS),IPRE(4),ISTYP(NS),
12.     E NSDAT(NMS)
13.     IF(IPRE(1).EQ.1)GOTO 200
14.     IF(NPROB.NE.0.AND.IOP.EQ.5)GOTO 500
15.     ZH=ZN(1)
16.     DO 100 I=1,NAM
17.     IF(ZN(I).GT.ZH) ZH=ZN(I)
18.     100 CONTINUE
19.     DO 200 NOB=1,NTOB
20.     WC=CENTF(NOB)
21.     W1=WC*(1-BW)
22.     W2=WC*(1+BW)
23.     DO 150 I=1,NAM
24.     IF(WNMC(I).GT.WC) GOTO 155
25.     150 CONTINUE
26.     I=I-1
27.     155 WRB=WNMC(I)
28.     IF(ABS(WC-WNMC(I-1)).LT.ABS(WNMC(I)-WC)) WRB=WNMC(I-1)
29.     IF(I.LE.1)WRB=WNMC(1)
30.     CALL VICAL(WB,W1,W2,WRB,ZH)
31.     CALL RCAL(WMAX,WMIN,WB,WC,W1,W2,ZH,EPS)
32.     BNDWN(NOB,1)=WC-WMIN
33.     BNDWN(NOB,2)=WMAX-WC
34.     200 CONTINUE
35.     C****      CALCULATION OF BNDWM
36.     IF(IPRE(3).EQ.1)GOTO 1111
37.     DO 500 IS=1,NMS
38.     IF(NSDAT(IS).NE.0)GOTO 500
39.     IF(ISTYP(IS).EQ.0)GOTO 500
40.     ZH=0.0
41.     IR=2*NFS+NSTOR(IS)
42.     READ(L8*IR)(ZM(J),J=1,NTOB)
43.     DO 250 I=1,NTOB
44.     250 IF(ZM(I).GT.ZH)ZH=ZM(I)
45.     300 CONTINUE
46.     IR=NSTOR(IS)
47.     READ(L9*IR) WM
48.     DO 400 NOB=1,NTOB
49.     WC=CENTF(NOB)
50.     DO 350 I=1,NM(IS)
51.     IF(WM(1,I).GT.WC) GOTO 355
52.     350 CONTINUE
53.     I=I-1
54.     355 WRB=WM(1,I)
55.     IF(I.LE.1)WRB=WM(1,1)

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56.      W1=WC*(1-BW)
57.      W2=WC*(1+BW)
58.      CALL VICAL(WB,W1,W2,WRB,ZH)
59.      CALL RCAL(WMAX,WMIN,WB,WC,W1,W2,ZH,EPS)
60.      BNDWM(NO8,1)=WC-WMIN
61.      BNDWM(NO8,2)=WMAX-WC
62.      400 CONTINUE
63.      IR=NSTOR(IS)
64.      WRITE(115*IR)BNDWM
65.      500 CONTINUE
66.      WRITE(6,*)BNDWN
67.      WRITE(6,*)BNDWM
68.      1111 RETURN
69.      C*****
70.      SUBROUTINE VICAL(WD,W1,W2,WRB,ZH)
71.      COMPLEX X,Y
72.      G=(4*ZH**2*WRB**2-2*WRB**2)
73.      AL=-G/2.0
74.      PHI=(4*WRB**4-G**2)**0.5
75.      X=CMPLX(AL,PHI)
76.      Y=CSQRT(X)
77.      ALPHA1=REAL(Y)
78.      PHI1=AIMAG(Y)
79.      AAZ=-1.0/(4*ALPHA1)
80.      BBZ=0.0
81.      CCZ=-AAZ
82.      DDZ=-BBZ
83.      TERM1=(AAZ/2)*ALOG(W2**2+2*ALPHA1*W2+ALPHA1**2+PHI1**2)+((BBZ-
84.      *ALPHA1*AAZ)/PHI1)*ATAN((W2+ALPHA1)/PHI1)-((AAZ/2)*ALOG(W1**2+2*
85.      *ALPHA1*W1+ALPHA1**2+PHI1**2)+((BBZ-ALPHA1*AAZ)/PHI1)*ATAN((W1+
86.      *ALPHA1)/PHI1))
87.      TERM2=(CCZ/2)*ALOG(W2**2-2*ALPHA1*W2+ALPHA1**2+PHI1**2)+((CCZ*
88.      *ALPHA1+DDZ)/PHI1)*ATAN((W2-ALPHA1)/PHI1)-((CCZ/2)*ALOG(W1**2-2*
89.      *ALPHA1*W1+ALPHA1**2+PHI1**2)+((CCZ*ALPHA1+DDZ)/PHI1)*ATAN((W1-
90.      *ALPHA1)/PHI1))
91.      WD=(TERM1+TERM2)/(W2-W1)
92.      RETURN
93.      C*****
94.      SUBROUTINE RCAL(WMAX,WMIN,WB,WC,W1,W2,ZH,EPS)
95.      DO 100 K=1,2
96.      C=EPS*WB
97.      DW=BW*WRB
98.      W3=WRB
99.      IF(WRB.LT.WC.AND.K.EQ.2)W3=WC
100.     IF(WRB.GT.WC.AND.K.EQ.1)W3=WC
101.     CALL VICAL(W,W1,W2,W3,ZH)
102.     DETO=W-C
103.     WRO=W3
104.     IF(K.EQ.1)WR=WRO-DW
105.     IF(K.EQ.2)WR=WRO+DW
106.     NI= 10
107.     ER=5.0
108.     10 CALL VICAL(W,W1,W2,WR,ZH)
109.     DET=W-C
110.     IF(DETO.LT.0.0.AND.DET.LT.0.0)GOTO 20
111.     IF(DETO.GT.0.0.AND.DET.GT.0.0)GOTO 20
112.     FIRST=WRO

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113.      RAST=WR
114.      IF(K.EQ.2) GOTO 30
115.      FIRST=WR
116.      RAST=WRO
117.      GOTO 30
118.      20  WRO=WR
119.      DW=BW*WR
120.      IF(K.EQ.1) WR=WRO-DW
121.      IF(K.EQ.2) WR=WRO+DW
122.      DETO=DET
123.      IF(WR.LT.50.) GOTO 51
124.      GOTO 10
125.      C**** NEWTON RAPHSON ITERATION
126.      30  J=2
127.      XFQY0=FIRST
128.      YDETO=DETO
129.      XFQYN=RAST
130.      YDETN=DET
131.      NIT=0
132.      YMAX=AMAX1(ABS(YDETO),ABS(YDETN))
133.      40  EP=ABS(YDETN/YMAX)
134.      NIT=NIT+1
135.      IF(EP.LE.ER) GOTO 50
136.      IF(NIT.GT.NI) GOTO 50
137.      X1=XFQYN-XFQY0
138.      Y1=YDETN-YDETO
139.      XY1=X1/Y1
140.      WR=XFQYN-YDETN*XY1
141.      IF(WR.LT.50.) GOTO 51
142.      CALL VICAL(W,W1,W2,WR,ZH)
143.      DET=W-C
144.      XFQY0=XFQYN
145.      YDETO=YDETN
146.      XFQYN=WR
147.      YDETN=DET
148.      GOTO 40
149.      50  CONTINUE
150.      IF(WR.LT.FIRST.OR.WR.GT.RAST) WR=(FIRST+RAST)/2.0
151.      51  IF(WR.LT.50.) WR=0.
152.      IF(K.EQ.1) WMIN=WR
153.      IF(K.EQ.2) WMAX=WR
154.      100 CONTINUE
155.      RETURN
156.      END

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,S XX.MULCV,XX.

10RIA 12/14/93-18:38(56,)

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1.  C*****
2.      SUBROUTINE MULCV(WNMC,EIMTX,A,D,VLMN,VLMN1,WN,WMO,IGEMOV,
3.      CAREAO,V,CENTF,NAM,NAMMC,NOO,NOM,N1,N,NMO,NV,NI,DFQY,
4.      ENTOB,LBAND,MBAND,L16,L17,IOPMD,MCP,NG,VAL,TOT)
5.  C*
6.  C*
7.  C*   PERFORMS ACOUSTIC COMPONENT MODE SYNTHESIS
8.  C*
9.  C*
10.     COMMON/AREA3/ZERO,EPS,BW,ER
11.     DIMENSION WNMC(NAM),EIMTX(NOM,NOO),
12.     &VLMN(NAM,NMO),VLMN1(NAM,NMO),WN(4,NAM,NV),WMO(3,NMO,NOO)
13.     &IGEMOV(2,NOO),AREAO(NOO),V(INV),CENTF(ENTOB),IOPMD(MCP,NV)
14.     &VAL(NMO),TOT(NMO)
15.     DOUBLE PRECISION A(N1,N),D(N,N),DETBS,FTST
16.     DOUBLE PRECISION VLFT,VRT,FQYL,FQYR,DF,YMAX,DER,VRST,RAST,VLST
17.     NAM1=12
18.     WRITE(6,*)NOM,NOO,NG
19.     ISTD=0
20.     FOTLO=CENTF(LBAND)*(1.-BW)
21.     FOTHI=CENTF(MBAND)*(1.+BW)
22.     DO 4 I=1,MCP
23.     DO 4 J=1,NV
24.         4 IOPMD(I,J)=1
25.     ICT=NG
26.     WNMC(1)=0.0
27.     K=2
28.     FQYL=DFLOAT(FOTLO)
29.     DF=FQYL*DFLOAT(DFQY)
30.     WRITE(6,*)DF,DF
31.     CALL GOVERN(FQYL)
32.     CALL DETER(VLFT)
33.     WRITE(6,*)DF,DF
34.     DER=DFLOAT(ER)
35.     C***** STEP THROUGH FREQUENCY RANGE
36.     10 FQYR=FQYL+DF
37.     CALL GOVERN(FQYR)
38.     CALL DETER(VRT)
39.     WRITE(6,*)FQYL,VLFT,FQYR,VRT
40.     IF(FQYL.EQ.FQYR)STOP 'ENDLESS LOOP BEGUN'
41.     IF(FQYR.GT.DFLOAT(FOTHI).AND.K.LE.2)STOP 'NO FREQUENCIES IN RANGE'
42.     IF(VLFT*VRT)40,30,20
43.     20 VLFT=VRT
44.     FQYL=FQYR
45.     IF(ISTD.GE.2)DF=FQYL*DFLOAT(DFQY)
46.     IF(K.LE.2)DF=FQYR*.11500
47.     ISTD=ISTD+1
48.     GOTO 10
49.     30 FTST=FQYL
50.     VLST=VLFT
51.     GOTO 90
52.     C***** CLOSE IN ON NATURAL FREQUENCY
53.     40 IF(ISTD.LT.2)THEN
54.         DF=DF/2.00
55.         GOTO 10

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56.      ELSE
57.      ENDIF
58.      YMAX=DMAX1(DABS(VLFT),DABS(VRT))
59.      RAST=FQYR
60.      VRAST=VRT
61.      DO 80 NIT=1,NI
62.      FTST=(FQYL*VRT-FQYR*VLFT)/(VRT-VLFT)
63.      CALL GOVERN(FTST)
64.      CALL DETER(VLTST)
65.      WRITE(6,*)K,FTST,VLTST
66.      IF(DABS(VLTST/YMAX).LE.DER)GOTO 90
67.      IF((VLTST*VLFT).LT.0.00)GOTO 70
68.      FQYL=FTST
69.      VLFT=VLTST
70.      GOTO 80
71.      70 FQYR=FTST
72.      VRT=VLTST
73.      80 CONTINUE
74.      C**** STORE RESULT AND PREPARE FOR NEXT STEP
75.      90 WPMC(K)=REAL(FTST)
76.      CALL GOVERN(FTST)
77.      CALL VEC
78.      IF(K.GE.NAM1)GOTO 100
79.      FQYL=RAST
80.      VLFT=VRAST
81.      ICT=ICT-1
82.      IF(ICT.LE.0)CALL OPMD(REAL(FTST),K)
83.      IF(ICT.LE.0)ICT=NG
84.      K=K+1
85.      ISTEP=0
86.      GO TO 10
87.      100 CONTINUE
88.      WRITE(6,*)WPMC
89.      C
90.      RETURN
91.      C*****
92.      SUBROUTINE GOVERN(FQY)
93.      DOUBLE PRECISION FQY
94.      C**** FORMS THE GOVERNING MATRIX FOR ACOUSTIC COMPONENT MODE SYNTHESIS
95.      DO 10 I=1,N00*NOM
96.      DO 10 J=1,N00*NOM
97.      10 D(I,J)=0.000
98.      DO 30 I=1,N00
99.      DO 30 J=1,N00
100.      IF(J.GT.I)GOTO 30
101.      IF(I.NE.J) GO TO 20
102.      KV=IGEMOV(1,I)
103.      SGN=1.0
104.      CALL EMTX(KV,I,J,FQY,SGN)
105.      KV=IGEMOV(2,J)
106.      SGN=-1.0
107.      CALL EMTX(KV,I,J,FQY,SGN)
108.      IF(I.EQ.J) GO TO 30
109.      20 KV=C
110.      IF(IGEMOV(1,I).EQ.IGEMOV(1,J).OR.IGEMOV(1,I).EQ.IGEMOV(2,J))
111.      * KV=IGEMOV(1,I)
112.      IF(IGEMOV(2,I).EQ.IGEMOV(1,J).OR.IGEMOV(2,I).EQ.IGEMOV(2,J))

```

```

113.      * KV=IGEMOV(2,I)
114.      IF(KV.EQ.2) GO TO 30
115.      L=2
116.      IF(IGEMOV(1,I).EQ.IGEMOV(1,J).OR.IGEMOV(2,I).EQ.IGEMOV(2,J))
117.      * L=1
118.      SGN=(-1.)*L
119.      CALL EMTX(KV,I,J,FQY,SGN)
120.      30 CONTINUE
121.      IF(N00.EQ.1)GOTO 45
122.      DO 40 I=1,N00*NOM
123.      DO 40 J=I,N00*NOM
124.      40 D(I,J)=D(J,I)
125.      45 CONTINUE
126.      DETBS=DABS(D(1,1))
127.      DO 47 I=1,N00*NOM
128.      DO 47 J=1,N00*NOM
129.      47 D(I,J)=D(I,J)/DETBS
130.      RETURN
131.      C*****
132.      SUBROUTINE EMTX(NVOL,I,J,FQY,SGN)
133.      DOUBLE PRECISION FQY
134.      DOUBLE PRECISION S,S1,S2
135.      IF(IGEMOV(1,I).EQ.NVOL) INV=1
136.      IF(IGEMOV(2,I).EQ.NVOL) INV=2
137.      IR=(INV-1)*N00+I
138.      READ(L17*IR) VLNM
139.      IF(IGEMOV(1,J).EQ.NVOL) INV=1
140.      IF(IGEMOV(2,J).EQ.NVOL) INV=2
141.      IR=(INV-1)*N00+J
142.      READ(L17*IR) VLNM1
143.      C**** SELECT THE MOST IMPORTANT NAMMC ACOUSTIC MODES AND THE
144.      C**** OPENING MODE SET FOR THE NAMMC ACOUSTIC MODES
145.      M=IOPMD(K/NG+1,NVOL)
146.      5 CONTINUE
147.      L=0
148.      DO 50 NR=M,M+NOM-1
149.      L=L+1
150.      M1=(I-1)*NOM+L
151.      J1=0
152.      DO 40 MR=M,M+NOM-1
153.      J1=J1+1
154.      M2=(J-1)*NOM+J1
155.      S=0.00
156.      DO 10 NWN=1,NAM
157.      S2=DFLOAT(WN(1,NWN,NVOL))*2-FQY**2
158.      IF(DABS(S2).LT.1.00)S2=1.00
159.      S1=DFLOAT(VLNM1(NWN,MR)*VLNM(NWN,NR))/S2
160.      S=S+S1
161.      10 CONTINUE
162.      30 D(M1,M2)=(S/DFLOAT(VINVOL)/AREA0(I)/AREA0(J))+D(M1,M2)
163.      6 *DFLOAT(SGN)
164.      40 CONTINUE
165.      50 CONTINUE
166.      111 CONTINUE
167.      RETURN
168.      C*****
169.      SUBROUTINE VEC

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```

170.      DO 60 J=1,N
171.      DO 60 I=1,N1
172.      A(I,J)=D(I,J)
173.      60 CONTINUE
174.      M=1
175.      CALL DPINV(A,N1,M,N1,DETBS)
176.      DO 90 I=1,N00
177.      DO 90 J=1,NOM
178.      II=NOM*(I-1)+J
179.      EIMTX(J,I) = REAL(A(II,N))
180.      90 CONTINUE
181.      EIMTX(NOM,N00)=-1.C
182.      WRITE(L16,K)EIMTX
183.      WRITE(6,*)WNMC(K)
184.      WRITE(6,*)EIMTX
185.      112 CONTINUE
186.      RETURN
187.      C*****
188.      SUBROUTINE DETER(DET)
189.      DOUBLE PRECISION S,DET
190.      C*
191.      C* EFFICIENTLY CALCULATES DETERMINANT OF A SPARSE MATRIX
192.      DET=1.DO
193.      NM1=N-1
194.      DO 100 J=1,NM1
195.      S=D(J,J)
196.      DET=DET*S
197.      JP1=J+1
198.      DO 50 I=J,N
199.      50 D(J,I)=D(J,I)/S
200.      DO 75 J1=JP1,N
201.      IF(D(J1,J).EQ.C.DO)GOTO 75
202.      S=D(J1,J)/D(J,J)
203.      DO 60 I=J,N
204.      60 D(J1,I)=D(J1,I)-D(J,I)*S
205.      75 CONTINUE
206.      100 CONTINUE
207.      DET=DET*DETBS
208.      RETURN
209.      C*****
210.      C*****
211.      SUBROUTINE OPMD(W,K)
212.      DO 100 NVOL=1,NV
213.      DO 40 I=1,NM0
214.      40 VAL(I)=0.C
215.      DO 95 IS=1,N00
216.      INV=J
217.      IF(IGEMOV(1,IS).EQ.NVOL)INV=1
218.      IF(IGEMOV(2,IS).EQ.NVOL)INV=2
219.      IF(INV.EQ.C)GOTO 95
220.      IR=(INV-1)*N00+IS
221.      READ(L17*IR)VLNM
222.      DO 55 NR=1,NM0
223.      DO 50 NWN=1,NAM
224.      S2=WN(1,NWN,NVOL)**2-W**2
225.      IF(ABS(S2).LT.1.)S2=1.0
226.      VAL(NR)=VAL(NR)+VLNM(NWN,NR)**2/S2

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```
227.      50 CONTINUE
228.      WRITE(6,*)NR,VAL
229.      IF(VAL(NR).EQ.0)STOP 'NMO TOO HIGH'
230.      55 CONTINUE
231.      TOT(1)=0.0
232.      DO 60 I=1,NOM
233.      60 TOT(1)=TOT(1)+VAL(I)
234.      DO 70 I=2,NMO-NOM
235.      70 TOT(I)=TOT(I-1)-VAL(I-1)+VAL(I+NOM-1)
236.      TOTHI=TOT(1)
237.      DO 80 I=1,NMO
238.      IF(TOT(I).LT.TOTHI)GOTO 80
239.      TOTHI=TOT(I)
240.      ITOT=I
241.      80 CONTINUE
242.      95 CONTINUE
243.      IOPMD(K/NG+1,NVOL)=ITOT
244.      100 CONTINUE
245.      WRITE(6,*)K
246.      WRITE(6,*)(IOPMD(K,I),I=1,NV)
247.      NAMMC=NAMMC
248.      WMO(1,1,1)=WMO(1,1,1)
249.      RETURN
250.      END
```

FTN 1466 IBANK 580 DBANK 4 COMMON

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,S XX.VPNMC,XX.
1CR1A 12/14/93-18:39(17,)
1. C*****
2. SUBROUTINE VPNMC(WNMC,WN,NAM,NV,IGEMOV,N00,NOM,AREAO,NMO,EIMTX,
3. *PNMC,INDPN,NAMMC,VLMN,V,NPROBN,NAMT,NVT,L5,L6,L16,L17,IOPMD,
4. *MCP,NG)
5. C*
6. C*
7. C* CALCULATE THE MULTIPLE CAVITY ACOUSTIC CONSTANTS OF CONSTRAINT
8. C*
9. C*
10. DIMENSION WNMC(NAM),WN(4,NAM,NV),IGEMOV(2,N00),AREAO(N00)
11. *,VLMN(NAM,NMO),EIMTX(NOM,N00),PNMC(NAMMC),INDPN(NV,NAM)
12. *,V(NV),IOPMD(MCP,NV)
13. CHARACTER*70 PLACE
14. PLACE='SUBROUTINE VPNMC'
15. WRITE(6,*)PLACE
16. WRITE(6,*)MCP,NG,NAMMC
17. WRITE(6,*)IOPMD
18. PLACE='IGEMOV'
19. WRITE(6,*)PLACE
20. WRITE(6,*)IGEMOV
21. DO 9 I=1,NV
22. DO 8 J=1,NAM
23. C**** SELECT THE NEAREST NAMMC MODES AROUND EACH WNMC
24. DO 4 NWN=1,NAM
25. 4 IF(WN(1,NWN,I).GT.WNMC(J)) GO TO 5
26. 5 INDPN(I,J)=NWN-INT(NAMMC/2+.5)
27. IF(INDPN(I,J).LE.0) INDPN(I,J)=1
28. 8 CONTINUE
29. C****
30. IR=(NPROBN-1)*NVT+I
31. WRITE(L6*IR,ERR=111)(INDPN(I,J),J=1,NAM)
32. 9 CONTINUE
33. WRITE(6,*)INDPN
34. DO 6 I=1,NAMMC
35. PNMC(I)=0.0
36. 6 CONTINUE
37. DO 7 NVOL=1,NV
38. PNMC(1)=1.0
39. IR=(NPROBN-1)*NAMT*NVT+(NVOL-1)*NAMT+1
40. WRITE(L5*IR)PNMC
41. 7 CONTINUE
42. DO 1000 NWN=2,NAM
43. IF(NWN.GE.13)GOTO 1000
44. READ(L16*NWN)EIMTX
45. PLACE='EIMTX'
46. WRITE(6,*)PLACE
47. WRITE(6,*)NWN
48. WRITE(6,*)EIMTX
49. DO 500 NVOL=1,NV
50. C**** SELECT THE NOM MODES FOR USE
51. M=IOPMD(NWN/NG+1,NVOL)
52. C****
53. DO 15 I=1,NAMMC
54. 15 PNMC(I)=0.0
55. DO 100 ISUR=1,N00

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56.      IF(IGEMOV(1,ISUR).EQ.NVOL)GO TO 10
57.      IF(IGEMOV(2,ISUR).NE.NVOL) GO TO 100
58.      SGN = -1.0
59.      GO TO 20
60.      10 SGN= +1.0
61.      20 VAL=0.0
62.      IF(IGEMOV(1,ISUR).EQ.NVOL) INV=1
63.      IF(IGEMOV(2,ISUR).EQ.NVOL) INV=2
64.      IR=(INV-1)*N00+ISUR
65.      READ(17*IR)VLNM
66.      PLACE='VLNM VALUES'
67.      WRITE(6,*)ISUR,NVOL
68.      DO 21 I8=1,15
69.      21 WRITE(6,*) (VLNM(I8,J8),J8=1,NM0)
70.      NWNMC=INDPN(NVOL,NWN)+1
71.      DO 40 I=1,NAMMC
72.      VAL=0.0
73.      NWNMC=NWNMC+1
74.      NR=M-1
75.      DO 30 J=1,NCM
76.      NR=NR+1
77.      VAL= VLNM(NWNMC,NR)*EIMTX(J,ISUR)+ VAL
78.      30 CONTINUE
79.      40 PNMCI=PNMCI+SGN*(AREA0(ISUR)*NWNMC(NWN)**2*VAL)
80.      & /(WN(1,NWNMC,NVOL)**2-NWNMC(NWN)**2)/V(NVOL)
81.      100 CONTINUE
82.      IR=(INPROBN-1)*NAMT*NVT+(NVOL-1)*NAMT+NWN
83.      WRITE(15*IR,ERR=111) PNMCI
84.      WRITE(6,*)NWN
85.      WRITE(6,*)PNMCI
86.      500 CONTINUE
87.      1000 CONTINUE
88.      111 CONTINUE
89.      RETURN
90.      END

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FTN 536 IBANK 372 DBANK

,S XX.PRM CAL,XX.

10RIA 12/14/83-18:39(17,)

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1. SUBROUTINE PRMCAL(VLNMO,BPO,VMNPA,RMN,VLNM,CN,ZANN,RJA,AMN,
2. &WMO,OTM,OORG,ONODC,WM,STM,SORG,SNODC,WNMC,WN,VTH,VORG,VNODC,
3. &IGEMOV,ISV,IOTYP,ISTYP,IVTYP,MASSUR,NM,NSDAT,NSTOR,BNDWM,BNDWN,
4. &CENTF,ZNDATA,IPF,EX,PNMC,INDPN,AREA,AREAO,NOM,NOO,NAM,NMS,MX,NX,
5. &NS,MNSS,NTOB,NSMX,NPFC,MXS,NV,MXV,NAMMC,NMO,V,SC,NSC,ZMDAT,ZM,LN,
6. COMMON /AREA1/IOP,MOP(4),IPRE(4),IN,IOUT
7. COMMON/AREA2/L0,L1,L2,L3,L4,L5,L6,L7,L8,L9,L10,L11,L12,L13,
8. & L14,L15,L16,L17,L18
9. COMMON/AREA3/ZERO,EPS,BW
10. COMMON/AREA4/NFV,NFS,NPFC,NTOBT,NVT,NST,MXVT,MXST,NAMT,
11. & NSMT,MXT,NXT,NAMHCT,NSEACT
12. COMMON/AREA5/NPROB,NPROBN,MTAPE,NTAPE,LBAND,MBAND,IHBAND
13. COMMON/AREA8/RO,CO,VOL,PREF,PI
14. COMMON/AREA9/FAC,PSI,DPI,DN,UP
15. DOUBLE PRECISION FAC(57),PSI(60),DPI,DN,UP
16. DIMENSION VLNMO(NAM,NMO),BPO(MX,NX,NSMX),VMNPA(NAM),VLNM(NAM),
17. &CN(NAM,NS),ZANN(NAM),RJA(NTOB),
18. &WMO(3,NMO,NOO),OTM(3,3,NOO),OORG(3,NOO),ONODC(MXS,3,NOO),WM(3,NSMX
19. &),STM(3,3,NS),SORG(3,NS),SNODC(MXS,3,NS),WNMC(NAM),WN(4,NAM,NV),
20. &VTH(3,3,NV),VORG(3,NV),VNODC(MXV,3,NV),IGEMOV(2,NOO),ISV(NS),
21. &IOTYP(NOO),ISTYP(NS),IVTYP(NV),MASSUR(MNSS,NMS),NM(NMS),NSDAT(NS),
22. &NSTOR(NS),BNDWM(NTOB,2),BNDWN(NTOB,2),CENTF(NTOB),ZNDATA(NTOB,NS),
23. &IPF(NMS),EX(NPFC,NMS),PNMC(NAMMC),INDPN(NAM,NV),AREA(NS),
24. &AREAO(NOO),RMN(NAM,NV),VINV),SC(NSC,NS),AMN(NAM,NV),ZMDAT(NTOB),
25. & ZM(NSMX)
26. C*
27. C*
28. C* PARAMETERS NEEDED FOR MODAL ANALYSIS ARE CALCULATED
29. C* PRMCAL DIRECTS THE CALCULATION FLOW BASED ON VARIOUS USER DEFINED
30. C* VARIABLES AND OPTIONS. THE FOLLOWING ROUTINES ARE IN PRMCAL:
31. C* MULPRM: OPENING/VOLUME COUPLING FACTORS
32. C* GENMAS: MULTIPLE CAVITY GENERALIZED ACOUSTIC MASS
33. C* LNCAL: MASTER SURFACE/MULTIPLE CAVITY COUPLING FACTORS
34. C* ZANCAL: ACOUSTIC CAVITY DAMPING FACTORS
35. C* ZMCAL: STRUCTURAL DAMPING
36. C* RJACAL: JOINT ACCEPTANCE-FREQUENCY DOMAIN
37. C*
38. C*
39. C* SURT: SURFACE INTEGRATION BY GAUSSIAN QUADRATURE
40. C* GLO:
41. C* F:
42. C*
43. C* SLX: SURFACE INTEGRATION LIMITS AND GEOMETRY DEFINITION
44. C* SLY:
45. C* SGEOM:
46. C*
47. C* OLX: OPENING INTEGRATION LIMITS AND GEOMETRY DEFINITION
48. C* OLY:
49. C* OGEOM:
50. C*
51. C* SIM: MASTER SURFACE STRUCTURAL MODE SHAPE
52. C* OIM: OPENING MODE SHAPE
53. C* FN: MULTIPLE CAVITY ACOUSTIC MODE SHAPE
54. C* FNCAL: SUBVOLUME ACOUSTIC MODE SHAPE
55. C* PFCF: SURFACE PRESSURE FIELD

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56. C*      NORMS: STRUCTURAL MODE SHAPE NORMALIZATION FACTOR
57. C*      NORMA: SUBVOLUME ACOUSTIC MODE SHAPE NORMALIZATION FACTOR
58. C*
59. C*      ALIGN: ANALYTICAL CALCULATION OF THE OPENING/VOLUME COUPLING, LNM
60. C*      SOX:
61. C*      SOY:
62. C*      SOZ:
63. C*
64. C*      ANGF: ANALYTICAL CALCULATION OF GENERALIZED FORCE
65. C*      RVBJA:
66. C*      ATJA:
67. C*      PWJA:
68. C*
69. C*      PORTIONS OF MOST OF THE ABOVE ROUTINES ARE SUBJECT TO UPDATING
70. C*      WHEN ADDITIONAL SURFACE ELEMENTS, VOLUME ELEMENTS, AND/OR EXTERNAL
71. C*      PRESSURE FIELD TYPES ARE ADDED TO THE PROGRAM LIBRARIES.
72. C*
73. C*
74. C****   OPENING/VOLUME COUPLING FACTORS
75.       IF(LN.EQ.2) GOTO 10
76.       IF(LN.EQ.3) GOTO 30
77.       CALL MULPRM
78.       GOTO 100
79. C****   MULTIPLE CAVITY GENERALIZED ACOUSTIC MASS
80.       10 CALL GENMAS
81. C****   ACOUSTIC CAVITY DAMPING FACTORS
82.       20 IF(IPRE(2).EQ.1) GOTO 100
83.       CALL ZANCAL
84.       GOTO 100
85. C****   STRUCTURAL MODAL DAMPING ASSIGNMENT
86.       30 CONTINUE
87.       CALL ZMCAL
88. C****   MASTER SURFACE/MULTIPLE CAVITY COUPLING FACTORS
89.       IF(IPRE(3).EQ.1) GOTO 40
90.       IF(IOP.EQ.5) GOTO 40
91.       CALL LNMAL
92. C****   JOINT ACCEPTANCE - FREQUENCY DOMAIN
93.       40 CONTINUE
94.       IF(IPRE(4).EQ.1) GOTO 100
95.       CALL RJACAL
96. C****
97.       100 RETURN
98. C*****
99.       SUBROUTINE MULPRM
100. C*   OPENING/VOLUME COUPLING FACTORS ARE CALCULATED IN MULPRM. THE
101. C*   COUPLING FACTORS ARE USED IN MULCV TO CALCULATE THE MULTIPLE
102. C*   CAVITY ACOUSTIC RESPONSE CHARACTERISTICS. THE LNM CAN BE EITHER
103. C*   ANALYTICALLY OR NUMERICALLY CALCULATED. WHEN ANY NEW OPENING OR
104. C*   VOLUME TYPE IS ADDED TO THE PROGRAM LIBRARIES, THE LNM SOLUTION
105. C*   IS ASSUMED TO BE NUMERIC UNLESS OTHERWISE NOTED IN THIS ROUTINE.
106. C*
107. C*
108.       DIMENSION IA(3), CF(4,3)
109.       IW=1
110.       NOM=NOM
111. C*   CALCULATE THE ACOUSTIC MODE NORMALIZATION FACTOR FOR SUBCAVITIES
112. C*

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113.      DO 10 NVOL=1,NV
114.      DO 10 N=1,NAM
115.      CALL NORMA(DA,NVOL,N)
116.      10 AMN(N,NVOL)=DA
117.      DO 1000 ISUR=1,N00
118.      IS=ISUR
119.      DO 1000 INV=1,2
120.      NVOL=IGEMOV(INV,ISUR)
121.      C**** IDENTIFY THE LNM ANALYTIC SOLUTION ,LTYP, TO BE USED
122.      LTYP=0
123.      IF(IOTYP(ISUR).EQ.1.AND.IVTYP(NVOL).EQ.1)LTYP=1
124.      IF(IOTYP(ISUR).EQ.2.AND.IVTYP(NVOL).EQ.2)LTYP=2
125.      IF(IOTYP(ISUR).EQ.3.AND.IVTYP(NVOL).EQ.2)LTYP=3
126.      IF(IOTYP(ISUR).EQ.3.AND.IVTYP(NVOL).EQ.3)LTYP=4
127.      C*
128.      IF(LTYP.NE.0)GOTO 150
129.      C**** NUMERICAL CALCULATION OF LNM
130.      DO 100 NWN=1,NAM
131.      DO 100 MWM=1,NMO
132.      VLNMO(NWN,MWM)=0.0
133.      VLNMO(NWN,MWM)=SURI(IS,ISUR,NVOL,MWM,NWN,IN)/AREA0(ISUR)
134.      & /AMN(NWN,NVOL)
135.      100 CONTINUE
136.      GOTO 900
137.      C**** ANALYTIC CALCULATION OF LNM
138.      150 CALL ALIGN(LTYP,ISUR,NVOL,IA,CF)
139.      DO 200 NWN=1,NAM
140.      DO 200 MWM=1,NMO
141.      BX=SOX(LTYP,ISUR,NVOL,IA,CF,NWN,MWM)
142.      BY=SOY(LTYP,ISUR,NVOL,IA,CF,NWN,MWM)
143.      BZ=SOZ(LTYP,ISUR,NVOL,IA,CF,NWN,MWM)
144.      VLNMO(NWN,MWM)=BX*BY*BZ/AREA0(ISUR)/AMN(NWN,NVOL)
145.      IF(ABS(VLNMO(NWN,MWM)).LT.ZERO)VLNMO(NWN,MWM)=0.0
146.      200 CONTINUE
147.      C**** STORE VLNMO IN TEMPORARY FILE
148.      900 IR=(INV-1)*N00+ISUR
149.      WRITE(L17*IR) VLNMO
150.      1000 CONTINUE
151.      1111 RETURN
152.      C*****
153.      SUBROUTINE GENMAS
154.      C*
155.      C*
156.      C* CALCULATE THE GENERALIZED ACOUSTIC MASS OF THE MULTIPLE CAVITY
157.      C* SYSTEM,ALSO CALCULATE THE PORTION OF THE GENERALIZED MASS IN
158.      C* EACH SUBVOLUME.
159.      C*
160.      C*
161.      IF(IPRE(1).EQ.0) GOTO 10
162.      IR=NPROB
163.      READ(L3*IR)WNMC
164.      IR=NFV + NPROB
165.      READ(L3*IR)VMNPA
166.      IR=2*NFV + NPROB
167.      READ(L3*IR)ZANN
168.      GOTO 1111
169.      10 IF(NV.NE.1) GOTO 300

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170.      DO 200 I=1,NAM
171.      RMN(I,1)=1.0
172.      CALL NORMA(DMNS,1,I)
173.      WNMCI=WN(1,I,1)
174.      200 VMNPA(I)=DMNS**2
175.      IR=NPROBN
176.      WRITE(L4*IR)RMN
177.      VOL=V(1)
178.      GOTO 1111
179.      300 VMNPA(1)=1.0
180.      DO 301 I=1,NV
181.      301 RMN(1,I)=V(I)/VOL
182.      DO 600 NWN=2,NAM
183.      VMNPA(NWN)=0.0
184.      IF(NWN.GE.12)GOTO 600
185.      DO 500 NVOL=1,NV
186.      IR=(NPROBN-1)*NAMT*NVT+(NVOL-1)*NAMT+NWN
187.      READ(L5*IR)(PNMCI,I=1,NAMMC)
188.      A=0.0
189.      DO 400 NWNMC=1,NAMMC
190.      A=PNMCI(NWNMC)**2+A
191.      400 CONTINUE
192.      VMNPA(NWN)= VMNPA(NWN) + A/VOL* V(NVOL)
193.      RMN(NWN,NVOL)=A*V(NVOL)/VOL
194.      500 CONTINUE
195.      DO 550 I=1,NV
196.      550 RMN(NWN,I)=RMN(NWN,I)/VMNPA(NWN)
197.      600 CONTINUE
198.      WRITE(L4*NPROBN)RMN
199.      1111 CONTINUE
200.      IF(IPRE(1).EQ.1) GOTO 1112
201.      IR= NPROBN
202.      WRITE(L2*IR) WN
203.      IR=NPROBN
204.      WRITE(L3*IR)WNMC
205.      IR=NFW+NPROBN
206.      WRITE(L3*IR)VMNPA
207.      C
208.      C
209.      1112 RETURN
210.      C*****
211.      SUBROUTINE ZANCAL
212.      C*
213.      C*
214.      C* ACOUSTIC CAVITY DAMPING FACTORS ARE CALCULATED FROM THE ACOUSTIC
215.      C* ABSORPTION OF EACH SURFACE AND THE ACOUSTIC MODE SHAPES. ALL
216.      C* INTEGRATIONS ARE NUMERICAL. THE ACOUSTIC ABSORPTION OVER EACH
217.      C* SUBSURFACE IS ASSUMED TO BE CONSTANT. THE END RESULT IS AN
218.      C* ESTIMATION OF THE ACOUSTIC DAMPING OF EACH CAVITY MODE. IF THE
219.      C* CAVITY DAMPING IS GIVEN AS DATA, ZANCAL LOADS PLACES THE
220.      C* INFORMATION INTO THE CORRECT ARRAYS IN THE CORRECT UNITS.
221.      C*
222.      C* ABSORPTION COEF= 8*RO*CO/ZA WHERE ZA IS SURFACE IMPEDANCE
223.      C* DATA IS IN THE FORM OF ABSORPTION COEFFICIENT UNLESS
224.      C* EXPERIMENTAL CAVITY DAMPING IS SPECIFIED. THEN IT IS
225.      C* IN THE FORM OF C/CC (PERCENT OR CRITICAL DAMPING)
226.      IW=3

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227.      IF(MOP(3).NE.1) GOTO 20
228.      C**** IF CAVITY DAMPING SUPPLIED BY DATA
229.      ISUR=1
230.      DO 10 NWN=1,NAM
231.      10 ZANN(NWN)=ZA(WNMC(NWN),ISUR)
232.      GOTO 100
233.      C**** CALCULATION OF CN AND ZANN
234.      20 CONTINUE
235.      DO 15 NVOL=1,NV
236.      DO 15 N=1,NAM
237.      CALL NORMA(DA,NVOL,N)
238.      15 AMN(N,NVOL)=DA
239.      DO 30 NWN=1,NAM
240.      30 ZANN(NWN)=0.0
241.      IR=NFV+NPROB
242.      C**** LOAD PREVIOUSLY CALCULATED CN IF STILL VALID
243.      IF(IPRE(1).EQ.1) READ(L2*IR) CN
244.      C****
245.      DO 60 ISUR=1,NS
246.      IF(ISTYP(ISUR).EQ.0) GOTO 60
247.      IS=ISUR
248.      NVOL=ISV(ISUR)
249.      DO 50 NWN=1,NAM
250.      ZAN=ZA(WNMC(NWN),ISUR)
251.      C
252.      IF(IPRE(1).EQ.1) GOTO 40
253.      IR=(NPROBN-1)*NAMT*NVT+(NVOL-1)*NAMT+NWN
254.      READ(L5*IR)PNMC
255.      CN(NWN,ISUR)=SURI(IS,ISUR,NVOL,MWM,NWN,IW)
256.      C
257.      C
258.      40 CM=CN(NWN,ISUR)/ZAN
259.      ZANN(NWN)=ZANN(NWN)+RO*CO**2*CM/(2*VOL*VMNPA(NWN)*WNMC(NWN))
260.      50 CONTINUE
261.      60 CONTINUE
262.      IR=NFV+NPROBN
263.      WRITE(L2*IR) CN
264.      100 CONTINUE
265.      IR=2*NFV+NPROBN
266.      WRITE(L3*IR)ZANN
267.      1111 RETURN
268.      FUNCTION ZA(W,ISUR)
269.      DO 10 I=1,NTOB
270.      W2=CENF(I)+BW*CENF(I)
271.      IF(W.LE.W2) GOTO 15
272.      10 CONTINUE
273.      I=I-1
274.      15 ZA=ZNDATA(I,ISUR)/8./RO/CO
275.      IF(MOP(3).EQ.1)ZA=ZNDATA(I,ISUR)
276.      RETURN
277.      C*****
278.      SUBROUTINE ZMCAL
279.      C*
280.      C* ASSIGN THE DAMPING TO EACH STRUCTURAL MODE BASED ON THE BAND
281.      C* AVERAGE DAMPING DATA
282.      C*
283.      DO 100 ISUR=1,NMS

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284.      IF (ISTYP(ISUR).EQ.0) GOTO 100
285.      IR=2*NFS+NSTOR(ISUR)
286.      READ(L8*IR)ZMDAT
287.      IR=NSTOR(ISUR)
288.      READ(L9*IR)WM
289.      DO 75 MWM=1,NM(ISUR)
290.      DO 50 NOB=LBAND,MBAND
291.      W1=CENF(NOB)*(1-BW)
292.      W2=CENF(NOB)*(1+BW)
293.      IF (WM(1,MWM).GT.W2.OR.WM(1,MWM).LT.W1)GOTO 60
294.      50 CONTINUE
295.      NOB=NOB-1
296.      60 ZM(MWM)=ZMDAT(NOB)
297.      75 CONTINUE
298.      IR=NFS+NSTOR(ISUR)
299.      WRITE(L9*IR)ZM
300.      IR=NSTOR(ISUR)
301.      WRITE(L8*IR)NM(ISUR),ISTYP(ISUR),AREA(ISUR)
302.      100 CONTINUE
303.      RETURN
304.      C*****
305.      SUBROUTINE LNMAL
306.      C*
307.      C*
308.      C* MASTER SURFACE/MULTIPLE CAVITY COUPLING FACTORS,VLMN,ARE CALCULATED
309.      C* FOR THOSE STRUCTURAL/ACOUSTIC MODAL COMBINATIONS THAT HAVE
310.      C* SIGNIFICANT CONTRIBUTION TO THE SOLUTION. ALL INTEGRATIONS ARE
311.      C* NUMERICAL.
312.      C*
313.      C*
314.      IW=2
315.      DO 100 IS=1,NMS
316.      IF (ISTYP(IS).EQ.0) GOTO 100
317.      IF (IPRE(1).EQ.1.AND.NSDAT(IS).NE.0) GOTO 100
318.      IR=NSTOR(IS)
319.      READ(L9*IR)((WM(I,J),I=1,3),J=1,NM(IS))
320.      READ(L15*IR)BNDWM
321.      C* NOTE THAT THE AMN(NSM,1) ARRAY IS USED TO EFFICIENTLY
322.      C* NORMALIZE THE STRUCTURAL MODE SHAPES SUCH THAT THE
323.      C* GENERALIZED MASS IS 1.0
324.      DO 10 MWM=1,NM(IS)
325.      10 CALL NORMS(AMN(MWM,1),IS,MWM)
326.      C**** SKIP IF SURFACE TYPE DOES NOT USE BPQ
327.      GOTO(20,30,20,30,30,30,20,30),ISTYP(IS)
328.      C
329.      C
330.      20 READ(L12*IR)((BPQ(I,J,K),I=1,MX),J=1,NX),K=1,NM(IS))
331.      C****
332.      30 CONTINUE
333.      DO 60 MWM=1,NM(IS)
334.      M=1
335.      DO 50 NWN=1,NAM
336.      VLMN(NWN)=0.0
337.      C**** USE BNDWM AND BNDWN TO LIMIT LNM CALCULATIONS TO SIGNIFICANT TERMS
338.      C
339.      WC=(WNC(NWN)+WM(1,MWM))/2.0
340.      DO 35 NOB=1,NTOB

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341.      IF(CENTF(NOB).GT.WC)GOTO 36
342.      35 CONTINUE
343.      36 CONTINUE
344.      M=NOB
345.      IF(WC-WM(1,MWM).GT.BNDWM(NOB,1))GOTO 50
346.      IF(WM(1,MWM)-WC.GT.BNDWM(NOB,2))GOTO 50
347.      IF(WC-WNMC(NWN).GT.BNDWN(NOB,1))GOTO 50
348.      IF(WNMC(NWN)-WC.GT.BNDWN(NOB,2))GOTO 50
349.      C
350.      C
351.      C****
352.      37 CONTINUE
353.      DO 40 I=1,MNSS
354.      IF(MASSUR(I,IS).EQ.0) GOTO 50
355.      ISUR=MASSUR(I,IS)
356.      NVOL=ISV(ISUR)
357.      IF(NV.GT.1)THEN
358.      IR=(NPROBN-1)*NAMT*NVT+(INVOL-1)*NAMT+NWN
359.      READ(L5*IR)PNMC
360.      ELSE
361.      ENDIF
362.      40 VLNM(NWN)=VLNM(NWN)+ SURI(IS,ISUR,NVOL,MWM,NWN,IW)/AMN(MWM,1)
363.      IF(ABS(VLNM(NWN)).LT.ZERO)VLNM(NWN)=0.0
364.      VLNM(NWN)=VLNM(NWN)/AREA(IS)
365.      50 CONTINUE
366.      IR=(IS-1)*NSMT+MWM+NSMT*NST*(NPROBN-1)
367.      WRITE(L7*IR)VLNM
368.      60 CONTINUE
369.      100 CONTINUE
370.      1111 CONTINUE
371.      RETURN
372.      C*****
373.      SUBROUTINE RJACAL
374.      C*
375.      C*
376.      C* RJACAL CALCULATES THE JOINT ACCEPTANCE FOR MODAL ANALYSIS
377.      C* GIVEN A RANDOM EXTERNAL PRESSURE FIELD
378.      C*
379.      C*
380.      DIMENSION DX(8),DA(8)
381.      NGP=8
382.      IW=0
383.      NGP1=NGP/2
384.      CALL GLO(DA,DX,-1.0,1.0,NGP,NGP1)
385.      DO 100 IS=1,NMS
386.      IF(ISTYP(IS).EQ.0) GOTO 100
387.      ISUR=IS
388.      NVOL=0
389.      C**** IF DATA ON MASS STORAGE, THEN SKIP TO THE NEXT SURFACE
390.      IF(IPF(IS).EQ.0) GOTO 100
391.      C**** READ IN MODAL RESPONSE DATA
392.      IR=NSTOR(IS)
393.      READ(L9*IR) WM
394.      READ(L15*IR)BNDWM
395.      C* NOTE THAT THE AMN(NSM,1) ARRAY IS USED TO EFFICIENTLY
396.      C* NORMALIZE THE STRUCTURAL MODE SHAPES SUCH THAT THE
397.      C* GENERALIZED MASS IS 1.0

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398.      DO 10 MWM=1,NM(IS)
399.      10 CALL NORMS(AMN(MWM,1),IS,MWM)
400.      C**** BRANCH TO ANALYTIC CALCULATION OF RJA IF THE MODE DESCRIPTION
401.      C**** IS IN FOURIER SERIES FORM OR IS IT IS TO BE ANALYTICALLY CALCULAT
402.      IF(IPF(IS).EQ.4)GOTO 60
403.      GOTO(60,60,60,30,30,30,60,60),ISTYP(IS)
404.      C
405.      C
406.      C**** NUMERICAL CALCULATION OF RJA
407.      30 CONTINUE
408.      DO 50 MWM=1,NM(IS)
409.      DO 40 NOB=LBAND,MBAND
410.      RJA(NOB)=0.0
411.      IF(CENTF(NOB)-WM(1,MWM).GT.BNDWM(NOB,1))GOTO 40
412.      IF(WM(1,MWM)-CENTF(NOB).GT.BNDWM(NOB,2))GOTO 40
413.      C
414.      CALL SLX(AA,BB,IS)
415.      H3=(BB-AA)/2.0
416.      G3=(BB+AA)/2.0
417.      Q3=0.0
418.      C
419.      DO 8 L=1,NGP
420.      XM=H3*DX(L)+G3
421.      AK=H3*DA(L)
422.      CALL SLY(C2,D2,XM,IS)
423.      H1=(D2-C2)/2.0
424.      G1=(D2+C2)/2.0
425.      Q1=0.0
426.      C
427.      DO 6 I=1,NGP
428.      UI=H1*DX(I)+G1
429.      AI=H1*DA(I)
430.      C1=AA
431.      D1=BB
432.      H2=(D1-C1)/2.0
433.      G2=(D1+C1)/2.0
434.      Q2=0.0
435.      C
436.      DO 4 J=1,NGP
437.      VJ=H2*DX(J)+G2
438.      AJ=H2*DA(J)
439.      CALL SLY(C,D,VJ,IS)
440.      H=(D-C)/2.0
441.      G=(D+C)/2.0
442.      Q=0.0
443.      C
444.      DO 2 K=1,NGP
445.      WK=H*DX(K)+G
446.      CALL SGEOM(XM,UI,XV,YV,ZV,GFC,AJP,IS,ISUR,NVOL,IW)
447.      CALL SGEOM(VJ,WK,XV,YV,ZV,GF,AJ,IS,ISUR,NVOL,IW)
448.      2 Q=Q+DA(K)*SIM(XM,UI,IS,MWM)*SIM(VJ,WK,IS,MWM)*GF*GFC*
449.      E      AJ*AJP*PFCF(XM,UI,VJ,WK,CENTF(NOB),IS,IW)
450.      4 Q2=Q2+AJ*H*Q
451.      6 Q1=Q1+AI*Q2
452.      8 Q3=Q3+AK*Q1
453.      IF(ABS(Q3).LT.ZERO)Q3=0.0
454.      C

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455.      RJA(INOB)=Q3/AMN(MWM,1)**2/AREA(IS)**2
456.      40  CONTINUE
457.      IR=(NSTOR(IS)-1)*NSMT+MWM
458.      WRITE(L10*IR)RJA
459.      50  CONTINUE
460.      GOTO 100
461.      C
462.      C
463.      C**** ANALYTICAL CALCULATION OF RJA
464.      60 IF(IPF(IS).EQ.4)CALL PFCAL(IS)
465.      IF(IPF(IS).EQ.4)GOTO 100
466.      IF(ISTYP(IS).NE.2.AND.ISTYP(IS).LT.7) CALL ANJAFS(IS)
467.      IF(ISTYP(IS).EQ.2.OR.ISTYP(IS).GE.7) CALL ANJASS(IS)
468.      100 CONTINUE
469.      1111 RETURN
470.      C*****
471.      FUNCTION SURI(IS,ISUR,NVOL,MWM,NWN,IW)
472.      C*
473.      C*
474.      C* NUMERICAL INTEGRATIONS FOR ALL PARAMETERS EXCEPT THE JOINT
475.      C* ACCEPTANCE ARE OBTAINED BY SURI WITH GAUSSIAN QUADRATURE
476.      C* THE INTEGRATION IS TWO DIMENSIONAL AND CARRIED OUT IN THE SURFACE
477.      C* ELEMENT'S COORDINATE SYSTEM. THE INTEGRATION REQUIRES
478.      C* APPROPRIATELY DESCRIBED SURFACE LIMITS, THE SURFACE INTEGRATION
479.      C* JACOBIAN, AND THE GEOMETRY CORRECTION FACTOR. THE SURFACE LIMITS
480.      C* ARE SET IN SLX AND SLY. THE JACOBIAN AND THE GEOMETRY CORRECTION
481.      C* FACTOR ARE CALCULATED IN SGEOM.
482.      DIMENSION DX(8),DA(8)
483.      NGP=8
484.      NGP1=NGP/2
485.      CALL GLO(DA,DX,-1.0,1.0,NGP,NGP1)
486.      IF(IW.EQ.1) CALL OLX(AA,BB,ISUR)
487.      IF(IW.NE.1) CALL SLX(AA,BB,ISUR)
488.      H1=(BB-AA)/2.
489.      G1=(BB+AA)/2.
490.      Q1=0.
491.      DO 4 I=1,NGP
492.      UI=H1*DX(I)+G1
493.      AI=H1*DA(I)
494.      IF(IW.EQ.1)CALL OLY(C,D,UI,ISUR)
495.      IF(IW.NE.1)CALL SLY(C,D,UI,ISUR)
496.      H=(D-C)/2.
497.      G=(D+C)/2.
498.      Q=0.
499.      DO 3 J=1,NGP
500.      VJ=H*DX(J)+G
501.      3 Q=Q+DA(J)*F(UI,VJ,IS,ISUR,NVOL,IW,NWN,MWM)
502.      4 Q1=Q1+AI*H*Q
503.      SURI=Q1
504.      RETURN
505.      C*****
506.      SUBROUTINE GLO(DA,DX,C,D,NGP,NGP1)
507.      DIMENSION DX(NGP),DA(NGP),XX(8),A1(8)
508.      DATA (XX(I),A1(I), I=1,4)/
509.      & .9602898564,.1012285362
510.      & .,7966664774,.2223810344
511.      & .,5255324099,.3137066458

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512.      6.,.1834346424.,.3626837833/
513.      DMC=0.500*(D-C)
514.      DPC=0.500*(D+C)
515.      DO 2 I=1,NGP1
516.      NI=(NGP+1)-I
517.      DX(I)=-DMC*XX(I)+DPC
518.      DX(NI)=DMC*XX(I)+DPC
519.      DA(I)=DMC*A1(I)
520.      2 DA(NI)=DMC*A1(I)
521.      RETURN
522.      C*****
523.      FUNCTION F(XI,YI,IS,ISUR,NVOL,IW,NWN,MWM)
524.      IF(IW.NE.1) CALL SGEOM(XI,YI,XV,YV,ZV,GF,AJ,IS,
525.      &ISUR,NVOL,IW)
526.      GOTO(10,20,30,40),IW
527.      C**** CALCULATE LNM FOR MULCV
528.      10 CALL OGEOM(XI,YI,XV,YV,ZV,ISUR,NVOL,AJ)
529.      F=OIM(XI,YI,ISUR,MWM)*FNCAL(XV,YV,ZV,NVOL,NWN)*AJ
530.      GOTO 1111
531.      C**** CALCULATE LNM FOR STRUCTURE/MULTIPLE CAVITY
532.      20 F=SIM(XI,YI,IS,MWM)*FN(XV,YV,ZV,NVOL,NWN)*GF*AJ
533.      GOTO 1111
534.      C**** CALCULATE CN FOR ACOUSTIC DAMPING
535.      30 F=FN(XV,YV,ZV,NVOL,NWN)**2*GF*AJ
536.      GOTO 1111
537.      C**** CALCULATE QMW FOR GENERALIZED FORCE IN FREQUENCY DOMAIN
538.      40 F=SIM(XI,YI,IS,MWM)*PFCF(XC,YC,XP,YP,WC,IS,IW)*GF*AJ
539.      GOTO 1111
540.      C****
541.      1111 RETURN
542.      C*****
543.      C* SURFACE INTEGRATION LIMITS:SLX,SLY
544.      C* SURFACE TYPES: #1. RETANGULAR SHAPE WITH FOURIER SERIES MODE
545.      C* SHAPE DESCRIPTION.
546.      C* #2. THIN,HOMOGENEOUS,RETANGULAR PANEL WITH
547.      C* SIMPLY SUPPORTED EDGES.
548.      C* #3. CIRCULAR SHAPE WITH FOURIER SERIES MODE
549.      C* SHAPE DESCRIPTION.
550.      C* #4. THIN,HOMOGENEOUS,CIRCULAR PANEL WITH FIXED
551.      C* EDGES.
552.      C* #5. FRAME STIFFENED ORTHOTROPIC WHOLE SHELL
553.      C* #6. FRAME STIFFENED ORTHOTROPIC SHELL SEGMENT
554.      C*
555.      C*****
556.      SUBROUTINE SLX(AA,BB,ISUR)
557.      C*
558.      C* THE INTEGRATION LIMITS IN THIS COORDINATE DIRECTION ARE CONSTANTS
559.      C*
560.      GOTO(10,20,30,40,50,60,70,80),ISTYP(ISUR)
561.      C**** SURFACE ELEMENT TYPE #1.
562.      10 AA=0.0
563.      BB=SNODC(2,1,ISUR)
564.      GOTO 1111
565.      C**** SURFACE ELEMENT TYPE #2.
566.      20 AA=SNODC(4,1,ISUR)
567.      BB=SNODC(5,1,ISUR)
568.      GOTO 1111

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569.  C**** SURFACE ELEMENT TYPE #3.
570.    30  CONTINUE
571.      AA=0.0
572.      BB=SNODC(2,1,ISUR)
573.      GOTO 1111
574.  C**** SURFACE ELEMENT TYPE #4.
575.    40  CONTINUE
576.      AA=0.0
577.      BB=SNODC(2,1,ISUR)
578.      GOTO 1111
579.  C**** SURFACE ELEMENT TYPE #5.
580.    50  AA=SNODC(4,1,ISUR)
581.      BB=SNODC(5,1,ISUR)
582.      GOTO 1111
583.  C**** SURFACE ELEMENT TYPE #6.
584.    60  GOTO 50
585.  C**** SURFACE ELEMENT TYPE #7.
586.    70  GOTO 20
587.  C**** SURFACE ELEMENT TYPE #8.
588.    80  GOTO 20
589.    1111 RETURN
590.  C*****
591.      SUBROUTINE SLY(C,D,UI,ISUR)
592.  C*
593.  C* THE INTEGRATION LIMITS IN THIS COORDINATE DIRECTION CAN BE CONSTANT
594.  C* OR A FUNCTION OF THE FIRST COORDINATE
595.      C=UI
596.      GOTO(10,20,30,40,50,60,70,80),ISTYP(ISUR)
597.  C**** SURFACE ELEMENT TYPE #1.
598.    10  C=0.0
599.      D=SNODC(3,2,ISUR)
600.      GOTO 1111
601.  C**** SURFACE ELEMENT TYPE #2.
602.    20  C=SNODC(4,2,ISUR)
603.      D=SNODC(6,2,ISUR)
604.      GOTO 1111
605.  C**** SURFACE ELEMENT TYPE #3.
606.    30  CONTINUE
607.      C=0.0
608.      D=SNODC(3,2,ISUR)
609.      GOTO 1111
610.  C**** SURFACE ELEMENT TYPE #4.
611.    40  CONTINUE
612.      C=0.0
613.      D=2*PI
614.      GOTO 1111
615.  C**** SURFACE ELEMENT TYPE #5.
616.    50  CONTINUE
617.      C=ARCOS(SNODC(4,2,ISUR)/SNODC(3,2,ISUR))
618.      D=APCOS(SNODC(5,2,ISUR)/SNODC(3,2,ISUR))
619.      IF(D.LT.ZERO)D=2.*PI
620.      IF(SNODC(5,3,ISUR).LT.0.)D=D+PI
621.      GOTO 1111
622.  C**** SURFACE ELEMENT TYPE #6.
623.    60  GOTO 50
624.  C**** SURFACE ELEMENT TYPE #7.
625.    70  GOTO 20

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626. C**** SURFACE ELEMENT TYPE #8.
627. 80 GOTO 20
628. C****
629. 1111 RETURN
630. C*****
631. SUBROUTINE SGEOM(XI,YI,XV,YV,ZV,GF,AJ,IS,ISUR,NVOL,IW)
632. C*
633. C*
634. C* SGEOM CALCULATES SEVERAL GEOMETRY RELATED FACTORS FOR EACH
635. C* SURFACE
636. C* 1. THE THIRD DIMENSION,ZC,OF THE SURFACE AS A FUNCTION OF XC,YC
637. C* 2. THE JACOBIAN OF THE SURFACE'S COORDINATE SYSTEM AT XC,YC,ZC
638. C* 3. THE POSITION OF THE SURFACE POINT XC,YC,ZC IN THE ORIENTATION
639. C* COORDINATE SYSTEM OF THE ADJACENT SUBVOLUME
640. C*
641. C*
642. GOTO(10,20,30,40,50,60,70,80),ISTYP(ISUR)
643. C**** SURFACE ELEMENT TYPE #1.
644. 10 ZC=0.0
645. XC=XI
646. YC=YI
647. AJ=1.0
648. GF=1.0
649. GOTO 200
650. C**** SURFACE ELEMENT TYPE #2.
651. 20 CONTINUE
652. GOTO 10
653. C**** SURFACE ELEMENT TYPE #3.
654. 30 ZC=0.0
655. XC=XI
656. YC=YI
657. AJ=1.0
658. GF=1.0
659. GOTO 200
660. C**** SURFACE ELEMENT TYPE #4.
661. 40 ZC=0.0
662. XC=XI*COS(YI)
663. YC=XI*SIN(YI)
664. GF=1.0
665. AJ=XI
666. GOTO 200
667. C**** SURFACE ELEMENT TYPE #5.
668. 50 CONTINUE
669. XC=XI
670. YC=SNODC(3,2,ISUR)*SIN(YI)
671. ZC=SNODC(3,2,ISUR)*COS(YI)
672. AJ=SNODC(3,2,ISUR)
673. GF=1.0
674. GOTO 200
675. C**** SURFACE ELEMENT TYPE #6.
676. 60 GOTO 50
677. C**** SURFACE ELEMENT TYPE #7.
678. 70 IF(SC(2,IS).LT.0.)GOTO 10
679. R=SC(2,IS)
680. ZC=(R**2-YI**2)**0.5-(R**2-(SNODC(3,2,IS))**2)**0.5
681. XC=XI
682. YC=YI

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683.      GF=(1+YI**2/(R**2-YI**2))**0.5
684.      AJ=1.0
685.      GOTO 200
686.      C**** SURFACE ELEMENT TYPE #8.
687.      80 GOTO 20
688.      C
689.      C
690.      C**** CALCULATE THE MASTER SURFACE AND SUBVOLUME COORDINATES
691.      200 CONTINUE
692.      IF(IW.GE.4)GOTO 1111
693.      X=STM(1,1,ISUR)*XC+STM(1,2,ISUR)*YC+STM(1,3,ISUR)*ZC+SORG(1,ISUR)
694.      Y=STM(2,1,ISUR)*XC+STM(2,2,ISUR)*YC+STM(2,3,ISUR)*ZC+SORG(2,ISUR)
695.      Z=STM(3,1,ISUR)*XC+STM(3,2,ISUR)*YC+STM(3,3,ISUR)*ZC+SORG(3,ISUR)
696.      XP=X-VORG(1,NVOL)
697.      YP=Y-VORG(2,NVOL)
698.      ZP=Z-VORG(3,NVOL)
699.      XV=VTM(1,1,NVOL)*XP+VTM(1,2,NVOL)*YP+VTM(1,3,NVOL)*ZP
700.      YV=VTM(2,1,NVOL)*XP+VTM(2,2,NVOL)*YP+VTM(2,3,NVOL)*ZP
701.      ZV=VTM(3,1,NVOL)*XP+VTM(3,2,NVOL)*YP+VTM(3,3,NVOL)*ZP
702.      1111 RETURN
703.      C*****
704.      C* OPENING INTEGRATION LIMITS
705.      C* OPENING TYPES : #1. RETANGLE
706.      C* #2. CIRCLE
707.      C* #3. CONCENTRIC CIRCULAR ANNULOUS
708.      C*
709.      C*****
710.      SUBROUTINE OLX(AA,BB,ISUR)
711.      C**** INTEGRATION LIMITS IN THIS COORDINATE DIRECTION ARE CONSTANTS
712.      GOTO(10,20,30),IOTYP(ISUR)
713.      C**** OPENING ELEMENT TYPE #1.RETANGLE
714.      10 AA=0.0
715.      BB=ONODC(2,1,ISUR)
716.      GOTO 1111
717.      C**** OPENING ELEMENT TYPE #2.CIRCLE
718.      20 AA=0.0
719.      BB=ONODC(2,1,ISUR)
720.      GOTO 1111
721.      C**** OPENING ELEMENT TYPE #3.CONCENTRIC CIRCULAR ANNULOUS
722.      30 AA=ONODC(3,2,ISUR)
723.      BB=ONODC(2,1,ISUR)
724.      GOTO 1111
725.      C****
726.      1111 RETURN
727.      C*****
728.      SUBROUTINE OLY(C,D,UI,ISUR)
729.      C*
730.      C* INTEGRATION LIMITS IN THIS COORDINATE DIRECTION CAN BE CONSTANTS
731.      C* OR A FUNCTION OF THE FIRST COORDINATE DIRECTION
732.      C*
733.      C=UI
734.      GOTO(10,20,30),IOTYP(ISUR)
735.      C**** OPENING ELEMENT TYPE #1. RETANGLE
736.      10 C=0.0
737.      D=ONODC(3,2,ISUR)
738.      GOTO 1111
739.      C**** OPENING ELEMENT TYPE #2. CIRCLE

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740.      20 C=0.3
741.      D=2*PI
742.      GOTO 1111
743.      C**** OPENING ELEMENT TYPE #3. CONCENTRIC CIRCULAR ANNULOUS
744.      30 C=0.0
745.      D=2*PI
746.      GOTO 1111
747.      C*****
748.      1111 RETURN
749.      C*****
750.      SUBROUTINE OGEOM(XI,YI,XV,YV,ZV,ISUR,NVOL,AJ)
751.      C*
752.      C*
753.      C* OGEOM CALCULATES THE VOLUME COORDINATE SYSTEM POINT XV,YV,ZV
754.      C* FROM THE OPENING COORDINATE SYSTEM POINT XC,YC
755.      C*
756.      GOTO(10,20,30),IOTYP(ISUR)
757.      C**** OPENING TYPE #1. RECTANGLE
758.      10 XC=XI
759.      YC=YI
760.      AJ=1.0
761.      GOTO 200
762.      C**** OPENING TYPE #2. CIRCLE
763.      20 XC=XI*COS(YI),
764.      YC=XI*SIN(YI)
765.      AJ=XI
766.      GOTO 200
767.      C**** OPENING TYPE #3. CONCENTRIC CIRCLES
768.      30 GOTO 20
769.      200 CONTINUE
770.      ZC=0.0
771.      X=OTM(1,1,ISUR)*XC+OTM(1,2,ISUR)*YC+OTM(1,3,ISUR)*ZC+OORG(1,ISUR)
772.      Y=OTM(2,1,ISUR)*XC+OTM(2,2,ISUR)*YC+OTM(2,3,ISUR)*ZC+OORG(2,ISUR)
773.      Z=OTM(3,1,ISUR)*XC+OTM(3,2,ISUR)*YC+OTM(3,3,ISUR)*ZC+OORG(3,ISUR)
774.      XP=X-VORG(1,NVOL)
775.      YP=Y-VORG(2,NVOL)
776.      ZP=Z-VORG(3,NVOL)
777.      XV=VTM(1,1,NVOL)*XP+VTM(1,2,NVOL)*YP+VTM(1,3,NVOL)*ZP
778.      YV=VTM(2,1,NVOL)*XP+VTM(2,2,NVOL)*YP+VTM(2,3,NVOL)*ZP
779.      ZV=VTM(3,1,NVOL)*XP+VTM(3,2,NVOL)*YP+VTM(3,3,NVOL)*ZP
780.      RETURN
781.      C*****
782.      FUNCTION SIM(XC,YC,IS,MWM)
783.      C*
784.      C*
785.      C* STRUCTURAL MODE SHAPES FOR EACH SURFACE TYPE
786.      C*
787.      C*
788.      SIM=0.0
789.      M=WMM(2,MWM)
790.      N=WMM(3,MWM)
791.      GOTO(10,20,30,40,50,60,70,80),ISTYP(IS)
792.      C**** TYPE #1. RECTANGULAR SHAPE WITH FOURIER SERIES MODE DESCRIPTION
793.      10 XL=SNODC(2,1,IS)
794.      YL=SNODC(3,2,IS)
795.      DO 11 J=1,MX
796.      DO 11 K=1,NX

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797.      11  SIM=SIM+BPQ(J,K,MWM)*SIN(J*PI*XC/XL)*SIN(K*PI*YC/YL)
798.      GOTO 1111
799.      C****  TYPE #2. THIN, HOMOGENEOUS, RECTANGULAR PANEL WITH SIMPLY
800.      C****  SUPPORTED EDGES
801.      20  CONTINUE
802.      SIM=SIN(M*PI*XC/SNODC(2,1,IS))*SIN(N*PI*YC/SNODC(3,2,IS))
803.      GOTO 1111
804.      C****  TYPE #3. CIRCULAR SHAPE WITH FOURIER SERIES MODE DESCRIPTION
805.      30  GO TO 10
806.      C*      TYPE #4. THIN, HOMOGENEOUS, CIRCULAR PANEL WITH FIXED
807.      C*      EDGES.
808.      40  CONTINUE
809.      N=N-1
810.      SKN=(WM(1,MWM)/SC(1,IS))*0.5
811.      A1=SKN*PI
812.      A2=SKN*PI/SNODC(2,1,IS)*XC
813.      SIM=SIN(N*YC)*(BJ(A2,N)+BJ(A1,N)/BI(A1,N)*BI(A2,N))
814.      GOTO 1111
815.      C****  SURFACE TYPE #5. FRAME STIFFENED ORTHOTROPIC WHOLE SHELL
816.      50  CONTINUE
817.      SIM=SIN(M*PI*XC/SNODC(2,1,IS))*COS((N-1)*YC)
818.      GOTO 1111
819.      C****  SURFACE TYPE #6. FRAME STIFFENED ORTHOTROPIC SHELL SEGMENT
820.      60  AL=ARCOS(SNODC(6,2,IS)/SNODC(3,2,IS))
821.      SIM=SIN(M*PI*XC/SNODC(2,1,IS))*SIN(N*PI*YC/AL)
822.      GOTO 1111
823.      C****  SURFACE TYPE #7. B2N STYLE FE DATA MATCH
824.      70  R=SC(2,IS)
825.      XA=XC-(SNODC(2,1,IS)-BPQ(1,8,MWM)-BPQ(1,6,MWM))
826.      IF(R.LT.0.)YA=YC-(SNODC(3,2,IS)-BPQ(1,9,MWM)-BPQ(1,7,MWM))
827.      IF(R.GT.0.)YA=(R*ARCOS(SNODC(3,2,IS)/R)+BPQ(1,9,MWM)+
828.      & BPQ(1,7,MWM))-R*ARCOS(YC/R)
829.      SIM=SIN(M*PI*XA/BPQ(1,6,MWM))*SIN(N*PI*YA/BPQ(1,7,MWM))
830.      IF(XA.LT.0.0.OR.XA.GT.BPQ(1,6,MWM))SIM=C.0
831.      IF(YA.LT.0.0.OR.YA.GT.BPQ(1,7,MWM))SIM=C.0
832.      GOTO 1111
833.      C****  TYPE #8. ORTHOTROPIC RECTANGULAR PANEL WITH CLAMPED EDGES
834.      80  CONTINUE
835.      AP=0.661
836.      AQ=0.661
837.      IF(M.EQ.1)AP=.630
838.      IF(N.EQ.1)AQ=.630
839.      XA=PI*(M+.5)*XC/SNODC(2,1,IS)
840.      YA=PI*(N+.5)*YC/SNODC(3,2,IS)
841.      SIM=AP*(COSH(XA)-COS(XA) - SINH(XA)+SIN(XA))*
842.      & AQ*(COSH(YA)-COS(YA) - SINH(YA)+SIN(YA))
843.      GOTO 1111
844.      C
845.      C
846.      C
847.      1111 RETURN
848.      C*****
849.      FUNCTION OIM(XC,YC,ISUR,MWM)
850.      C*
851.      C*
852.      C*  OPENING MODE SHAPES
853.      M=WMO(2,MWM,ISUR)

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854.      N=WMO(3,MWM,ISUR)
855.      OIM=0.0
856.      C*
857.      GOTO(10,20,30),IOTYP(ISUR)
858.      C**** OPENING ELEMENT TYPE #1.RETANGLE
859.      10  OIM=COS(M*PI*XC/ONODC(2,1,ISUR))*COS(N*PI*YC/ONODC(3,2,ISUR))
860.      GOTO 1111
861.      C**** OPENING ELEMENT TYPE #2. CIRCLE
862.      20  B=WMO(1,MWM,ISUR)*XC
863.      OIM=COS(N*YC)*BJ(B,N)
864.      GOTO 1111
865.      C**** OPENING ELEMENT TYPE #3. CONCENTRIC CIRCULAR ANNULOUS
866.      30  CONTINUE
867.      B=WMO(1,MWM,ISUR)*XC
868.      B1=WMO(1,MWM,ISUR)*ONODC(2,1,ISUR)
869.      E=BJP(B1,N)/BYP(B1,N)
870.      OIM=COS(N*YC)*(BJ(B,N)-E*BY(B,N))
871.      GOTO 1111
872.      C****
873.      C
874.      C
875.      1111 RETURN
876.      C*****
877.      FUNCTION FN(XV,YV,ZV,NVOL,NWN)
878.      C*
879.      C*
880.      C* FN CALCULATES THE MULTIPLE CAVITY ACOUSTIC MODE SHAPES
881.      C*
882.      C*
883.      IF(NV.NE.1) GOTO 10
884.      FN=FNCL(XV,YV,ZV,NVOL,NWN)
885.      GOTO 1111
886.      10  FN=0.0
887.      N=INDPN(NWN,NVOL)-1
888.      DO 50 I=1,NAHMC
889.      N=N+1
890.      FN=FN+FNCL(XV,YV,ZV,NVOL,N)*PNMC(I)/AMN(N,NVOL)
891.      50  CONTINUE
892.      1111 RETURN
893.      C*****
894.      FUNCTION FNCL(XV,YV,ZV,NVOL,NWN)
895.      C*
896.      C*
897.      C* FNCL CALCULATES THE ACOUSTIC MODE SHAPES OF THE SUBVOLUMES OF
898.      C* THE MULTIPLE CAVITY SYSTEM. XV,YV,ZV, ARE ALWAYS IN THE ACOUSTIC
899.      C* COMPONENTS ORIENTATION COORDINATE SYSTEM (RETANGULAR). THE MODE
900.      C* SHAPES ARE ALL NORMALIZED SUCH THAT THE GENERALIZED MASS OF THE
901.      C* SUBVOLUME ACOUSTICS IS 1.0. BY THE NORMALIZATION FACTOR AMN(NAM,NV)
902.      C*
903.      C*
904.      M=INT(WN(2,NWN,NVOL))
905.      N=INT(WN(3,NWN,NVOL))
906.      IS=INT(WN(4,NWN,NVOL))
907.      GO TO (10,20,30,40),IVTYP(NVOL)
908.      C**** VOLUME ELEMENT TYPE #1. RETANGULAR PARALLOPIPED
909.      10  CONTINUE
910.      FNCL=ICOS(M*PI*XV/VNODC(2,1,NVOL))*COS(N*PI*YV/VNODC(3,2,NVOL)

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911.      0))*COS(15*PI*ZV/VNODC(4,3,NVOL)))
912.      GOTO 1111
913.      C**** VOLUME ELEMENT TYPE #2. CIRCULAR CYLINDER
914.      20 CONTINUE
915.      BETA=(WN(1,NWN,NVOL)**2/CO**2-(15*PI/VNODC(4,3,NVOL))**2)
916.      BETA=(ABS(BETA))**.5
917.      RR=(XV**2+YV**2)**.5
918.      IF(RR.GT.VNODC(2,1,NVOL))RR=VNODC(2,1,NVOL)
919.      SKN=BETA*RR
920.      TH=ARCOS(XV/RR)
921.      FNCAL=COS(15*PI*ZV/VNODC(4,3,NVOL))*COS(N*TH)*BJ(SKN,N)
922.      GOTO 1111
923.      C**** VOLUME ELEMENT #3. ANNULOUS OF CONCENTRIC CIRCULAR CYLINDERS
924.      30 CONTINUE
925.      BETA=(WN(1,NWN,NVOL)/CO**2-(15*PI/VNODC(4,3,NVOL))**2)
926.      BETA=(ABS(BETA))**.5
927.      Rp=(XV**2+YV**2)**.5
928.      IF(RR.GT.VNODC(2,1,NVOL))RR=VNODC(2,1,NVOL)
929.      SKN=BETA*RR
930.      TH=ARCOS(XV/RR)
931.      RKB=BETA*VNODC(3,2,NVOL)
932.      FNCAL=COS(15*PI*ZV/VNODC(4,3,NVOL))*COS(N*TH)*
933.      0 (BJ(SKN,N)-BJP(RKB,N)/BYP(RKB,N)*BY(SKN,N))
934.      IF(BETA.LT.ZERO)FNCAL=FNCAL*1.0
935.      GOTO 1111
936.      C**** VOLUME ELEMENT TYPE #4. PERTURBED PARALLELEPIPED
937.      40 IF(ZV.GT.VNODC(4,3,NVOL))ZV=VNODC(4,3,NVOL)
938.      GOTO 10
939.      C****
940.      1111 RETURN
941.      C*****
942.      FUNCTION PFCF(XC,YC,XP,YP,WC,IS,IW)
943.      C*
944.      C*
945.      C* PFCF CALCULATES THE PRESSURE CORRELATION FUNCTION (FOR RANDOM
946.      C* FIELDS) AND THE SURFACE PRESSURE DISTRIBUTION (FOR DETERMINISTIC
947.      C* FIELDS). THE POINTS XC,YC,ZC,XP,YP,ZP ARE IN THE COORDINATE SYSTEM
948.      C* OF INTEGRATION.
949.      C*
950.      C*
951.      IW=IW
952.      GOTO(10,20,30),IPF(IS)
953.      C**** PRESSURE FIELD TYPE #1. REVERBERANT PRESSURE FIELD
954.      10 PK=WC/CO
955.      PFCF=SIN(RK*(XC-XP))/(RK*(XC-XP))*SIN(RK*(YC-YP))/(RK*(YC-YP))
956.      GOTO 1111
957.      C**** PRESSURE FIELD TYPE #2. AERODYNAMIC TURBULENCE
958.      20 RKX=EX(2,IS)*WC/CO
959.      RKY=EX(4,IS)*WC/CO
960.      PFCF=EXP(-1*EX(1,IS)*RKX*ABS(XC-XP))*COS(RKX*ABS(XC-XP))
961.      5*EXP(-1*EX(3,IS)*RKY*ABS(YC-YP))*COS(RKY*ABS(YC-YP))
962.      GOTO 1111
963.      C**** PRESSURE FIELD TYPE #3. PLANE WAVE FIELD
964.      30 CONTINUE
965.      RK=WC/CO*COS(EX(1,IS))
966.      PFCF=COS(RK*(XC-XP))
967.      GOTO 1111

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968. C****
969. 1111 RETURN
970. C*****
971. SUBROUTINE NORMA(DMNS,NVOL,NWN)
972. C*
973. C* CALCULATES THE NORMALIZATION FACTOR FOR THE ACOUSTIC MODE SHAPES
974. C*
975. M=NINT(WN(2,NWN,NVOL))
976. N=NINT(WN(3,NWN,NVOL))
977. IS=NINT(WN(4,NWN,NVOL))
978. GOTO(10,20,30),IVTYP(NVOL)
979. C**** VOLUME TYPE #1. RETANGULAR PARALLOPIPED
980. 10 EM=1.0
981. EN=1.0
982. ES=1.0
983. IF(M.EQ.0)EM=2.0
984. IF(N.EQ.0)EN=2.0
985. IF(IS.EQ.0)ES=2.0
986. DMNS=(EM*EN*ES/8.0)**.5
987. GOTO 1111
988. C**** VOLUME TYPE #2. CIRCULAR CYLINDER
989. 20 EN=1.0
990. ES=1.0
991. IF(N.EQ.0)EN=2.0
992. IF(IS.EQ.0)ES=2.0
993. IF(N.EQ.0.AND.M.EQ.1)GOTO 25
994. RKNM=(WN(1,NWN,NVOL)**2/C0**2-(IS*PI/VNODC(4,3,NVOL))**2)**0.5
995. RKNM=RKNM*VNODC(2,1,NVOL)
996. DMNS=((BJP(RKNM,N)**2+(1-N**2/RKNM**2)*BJ(RKNM,N)**2)*EN*ES/4.)
997. & **0.5
998. GOTO 1111
999. 25 DMNS=(EN*ES/4.)*0.5
1000. GOTO 1111
1001. C**** VOLUME TYPE #3. CONCENTRIC CIRCULAR CYLINDER ANNULOUS
1002. 30 EN=1.0
1003. ES=1.0
1004. IF(N.EQ.0)EN=2.0
1005. IF(IS.EQ.0)ES=2.0
1006. RKNM=(WN(1,NWN,NVOL)**2/C0**2-(IS*PI/VNODC(4,3,NVOL))**2)**0.5
1007. RKA=RKNM*VNODC(4,2,NVOL)
1008. RKB=RKNM*VNODC(2,1,NVOL)
1009. DMNS=(ES*EN/4.0*((VNODC(2,1,NVOL)**2-N**2/RKNM**2)*
1010. & (BJ(RKB,N)-BJP(RKB,N)/BYP(RKB,N)*BY(RKB,N))**2-
1011. & (VNODC(4,2,NVOL)**2-N**2/RKNM**2)
1012. & *(BJ(RKA,N)-BJP(RKB,N)/BYP(RKB,N)*BY(RKA,N))**2))**0.5
1013. GOTO 1111
1014. 1111 RETURN
1015. C*****
1016. SUBROUTINE NORMS(DMN,ISUR,MWM)
1017. C*
1018. C* CALCULATES THE NORMALIZATION FACTOR FOR THE STRUCTURAL MODE SHAPE
1019. C*
1020. M=INT(WM(2,MWM))
1021. N=INT(WM(3,MWM))
1022. GOTO(10,20,30,40,50,60,70,80),ISTYP(ISUR)
1023. C**** SURFACE TYPE #1. RETANGULAR PANEL (SINE SERIES)
1024. 10 DMN=1.0

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1025.      GOTO 1111
1026.  C**** SURFACE TYPE #2. RECTANGULAR HOMOGENEOUS PANEL WITH SIMPLY
1027.  C      SUPPORTED EDGES
1028.      20 CONTINUE
1029.      DMN=(SC(6,ISUR)*SNODC(2,1,ISUR)*SNODC(3,2,ISUR)/4.)*.5
1030.      GOTO 1111
1031.  C**** SURFACE TYPE #3. CIRCULAR PANEL (SINE SERIES)
1032.      30 CONTINUE
1033.      DMN=1.0
1034.      GOTO 1111
1035.  C**** SURFACE TYPE #4. CIRCULAR PANEL WITH FIXED EDGES
1036.      40 EN=1.0
1037.      IF(N.EQ.0) EN=2.0
1038.      RKA= (WM(1,MWM)/SC(1,ISUR))*0.5*PI
1039.      DMN=EM/2.0*((BJP(RKA,N)**2+(1-N**2/RKA**2)*BJ(RKA,N)**2)
1040.      & +2.*BJ(RKA,N)**2+(1-N**2/RKA**2)*BI(RKA,N)**2)
1041.      & +(BJ(RKA,N)/BI(RKA,N))**2*(BIP(RKA,N)**2+(1-N**2/RKA**2)*
1042.      & BI(RKA,N)**2))
1043.      DMN=(DMN*SC(2,ISUR)*AREA(ISUR))*0.5
1044.      GOTO 1111
1045.  C**** SURFACE TYPE #5. FRAME STIFFENED ORTHOTROPIC WHOLE SHELL
1046.      50 N=N-1
1047.      EM=1.0
1048.      EN=1.0
1049.      IF(M.EQ.0)EM=2.0
1050.      IF(N.EQ.0)EN=2.0
1051.      DMN=(EM*EN/4.*SC(2,ISUR)*AREA(ISUR))*0.5
1052.      GOTO 1111
1053.  C**** SURFACE TYPE #6. FRAME STIFFENED ORTHOTROPIC SHELL SEGMENT
1054.      60 GOTO 50
1055.  C**** SURFACE TYPE #7. BBN FE DATA MODEL
1056.      70 DMN=2.*0.5*BPQ(1,4,MWM)*BPQ(1,5,MWM)
1057.      GOTO 1111
1058.  C**** SURFACE TYPE #8. RECTANGULAR ORTHOTROPIC PANEL WITH FIXED PANELS
1059.      80 CONTINUE
1060.      VMS=SC(6,ISUR)*SNODC(2,1,ISUR)*SNODC(3,2,ISUR)
1061.      IF(M.EQ.1)FX=.396
1062.      IF(N.EQ.1)FY=.396
1063.      IF(M.EQ.2)FX=.439
1064.      IF(N.EQ.2)FY=.439
1065.      IF(M.EQ.3)FX=.437
1066.      IF(N.EQ.3)FY=.437
1067.      DMN=(FX*FY*VMS)*0.5
1068.      1111 RETURN
1069.  C*****
1070.      SUBROUTINE ALIGN(LTYP,ISUR,NVOL,IA,CF)
1071.  C*
1072.  C*
1073.  C* ALIGN CALCULATES THE GEOMETRIC PARAMETERS NEEDED FOR THE
1074.  C* ANALYTIC SOLUTION OF LNM. THE SUBROUTINE'S PARAMETER LIST MAY
1075.  C* BE USED AS REQUIRED TO PROVIDE THE APPROPRIATE INFORMATION TO
1076.  C* SOX,SOY,SOZ FOR NEW ADDITIONS TO THE LIBRARY.
1077.  C*
1078.  C*
1079.      DIMENSION IA(3),CF(4,3)
1080.      GOTO(10,20,30,40),LTYP
1081.  C**** ANALYTIC INTEGRATION: SURFACE TYPE #1/VOLUME TYPE #1 (LTYP=1)

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1082.      10  CF(4,1)=ONODC(2,1,ISUR)
1083.      CF(4,2)=ONODC(3,2,ISUR)
1084.      CALL PXFER(X1,Y1,Z1,1,ISUR,NVOL)
1085.      CALL PXFER(X2,Y2,Z2,2,ISUR,NVOL)
1086.      CALL PXFER(X3,Y3,Z3,3,ISUR,NVOL)
1087.      XPX=X2-X1
1088.      YPX=Y2-Y1
1089.      ZPX=Z2-Z1
1090.      XPY=X3-X1
1091.      YPY=Y3-Y1
1092.      ZPY=Z3-Z1
1093.      IF(ABS(XPX).LT.ZERO) GO TO 11
1094.      CF(1,1)=XPX/ABS(XPX)
1095.      CF(2,1)=X1
1096.      CF(3,1)=VNODC(2,1,NVOL)
1097.      IA(1)=2
1098.      11  IF(ABS(YPX).LT.ZERO) GO TO 12
1099.      CF(1,1)=YPX/ABS(YPX)
1100.      CF(2,1)=Y1
1101.      CF(3,1)=VNODC(3,2,NVOL)
1102.      IA(1)=3
1103.      12  IF(ABS(ZPX).LT.ZERO) GO TO 13
1104.      CF(1,1)=ZPX/ABS(ZPX)
1105.      CF(2,1)=Z1
1106.      CF(3,1)=VNODC(4,3,NVOL)
1107.      IA(1)=4
1108.      13  IF(ABS(XPY).LT.ZERO) GO TO 14
1109.      CF(1,2)=XPY/ABS(XPY)
1110.      CF(2,2)=X1
1111.      CF(3,2)=VNODC(2,1,NVOL)
1112.      IA(2)=2
1113.      14  IF(ABS(YPY).LT.ZERO) GO TO 15
1114.      CF(1,2)=YPY/ABS(YPY)
1115.      CF(2,2)=Y1
1116.      CF(3,2)=VNODC(3,2,NVOL)
1117.      IA(2)=3
1118.      15  IF(ABS(ZPY).LT.ZERO) GO TO 16
1119.      CF(1,2)=ZPY/ABS(ZPY)
1120.      CF(2,2)=Z1
1121.      CF(3,2)=VNODC(4,3,NVOL)
1122.      IA(2)=4
1123.      16  IF(IA(1)+IA(2).NE.7) GO TO 17
1124.      CF(1,3)=0.0
1125.      CF(2,3)=X1
1126.      CF(3,3)=VNODC(2,1,NVOL)
1127.      IA(3)=2
1128.      17  IF(IA(1)+IA(2).NE.6) GO TO 18
1129.      CF(1,3)=0.0
1130.      CF(2,3)=Y1
1131.      CF(3,3)=VNODC(3,2,NVOL)
1132.      IA(3)=3
1133.      18  IF(IA(1)+IA(2).NE.5) GO TO 19
1134.      CF(1,3)=0.0
1135.      CF(2,3)=Z1
1136.      CF(3,3)=VNODC(4,3,NVOL)
1137.      IA(3)=4
1138.      19  CONTINUE

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1139.      GOTO 1111
1140.      C**** OPENING/VOLUME COMBINATIONS 2,3,4 REQUIRE THE SAME ALIGNMENT
1141.      2C CONTINUE
1142.      3C CONTINUE
1143.      4C CONTINUE
1144.      CALL PXFER(X1,Y1,Z1,1,ISUR,NVOL)
1145.      CF(1,1)=Z1
1146.      CF(1,2)=VNODC(4,3,NVOL)
1147.      GOTO 1111
1148.      1111 RETURN
1149.      C*****
1150.      SUBROUTINE PXFER(XN,YN,ZN,N,ISUR,NVOL)
1151.      C*
1152.      C*
1153.      C* PXFER CALCULATES THE LOCATION OF THE N. TH SURFACE NODE OF ISUR
1154.      C* IN THE COORDINATE SYSTEM OF SUBVOLUME NVOL.
1155.      C*
1156.      C*
1157.      XC=ONODC(N,1,ISUR)
1158.      YC=ONODC(N,2,ISUR)
1159.      ZC=ONODC(N,3,ISUR)
1160.      X=OTM(1,1,ISUR)*XC+OTM(1,2,ISUR)*YC+OTM(1,3,ISUR)*ZC+OORG(1,ISUR)
1161.      Y=OTM(2,1,ISUR)*XC+OTM(2,2,ISUR)*YC+OTM(2,3,ISUR)*ZC+OORG(2,ISUR)
1162.      Z=OTM(3,1,ISUR)*XC+OTM(3,2,ISUR)*YC+OTM(3,3,ISUR)*ZC+OORG(3,ISUR)
1163.      X=X-VORG(1,NVOL)
1164.      Y=Y-VORG(2,NVOL)
1165.      Z=Z-VORG(3,NVOL)
1166.      XN=VTM(1,1,NVOL)*X+VTM(1,2,NVOL)*Y+VTM(1,3,NVOL)*Z
1167.      YN=VTM(2,1,NVOL)*X+VTM(2,2,NVOL)*Y+VTM(2,3,NVOL)*Z
1168.      ZN=VTM(3,1,NVOL)*X+VTM(3,2,NVOL)*Y+VTM(3,3,NVOL)*Z
1169.      RETURN
1170.      C*****
1171.      FUNCTION SOX(LTYP,ISUR,NVOL,IA,CF,NWN,MWM)
1172.      C*
1173.      C*
1174.      C* SOX ANALYTICALLY CALCULATES THE X-COMPONENT OF LNM FOR COMPONENT
1175.      C* MODE SYNTHESIS (IN MULCV). LNM IS ALWAYS CALCULATED OVER THE
1176.      C* ENTIRE OPENING.
1177.      C*
1178.      C*
1179.      C* ISUR: OPENING NUMBER
1180.      C* NVOL: VOLUME NUMBER
1181.      C* LTYP: OPENING/VOLUME INTEGRATION TYPE
1182.      C*
1183.      C* IA: ARRAY OF INTEGER CONSTANTS
1184.      C* CF: ARRAY OF REAL CONSTANTS FOR ANALYTIC INTEGRATION
1185.      C*
1186.      DIMENSION IA(3),CF(4,3)
1187.      ISUR=ISUR
1188.      GOTO(10,20,30,40),LTYP
1189.      C*** TYPE #1. RETANGLE/RETANGULAR PARALLOPIPED
1190.      10 A=CF(2,1)
1191.      A1=CF(3,1)
1192.      XL=CF(4,1)
1193.      I=WN(IA(1),NWN,NVOL)
1194.      IP=WMO(2,MWM,ISUR)
1195.      IF(ABS(XL-A1).GT.ZERO) GOTO 17

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1196.      IF(I+IP.EQ.0)GOTO 11
1197.      IF(I-IP.NE.0) GOTO 15
1198.      IF(I-IP.EQ.0) GOTO 16
1199.      11 SOX=XL
1200.      GOTO 1111
1201.      15 SOX=0.0
1202.      GOTO 1111
1203.      16 SOX=0.5*XL
1204.      GOTO 1111
1205.      17 YCM1=A1-XL
1206.      T1=PI*XL/A1
1207.      TT1=PI*A/A1
1208.      VMYM=IP/XL
1209.      VNYYC=I/A1
1210.      IF(I+IP.EQ.0) GOTO 12
1211.      VM2=VNYYC-VMYM
1212.      IF(ABS(VM2).LT.ZERO)VM2=0.0
1213.      IF(A.EQ.0..AND.VM2.EQ.0.) GOTO 13
1214.      BETA=I*TT1
1215.      IF(A.NE.0.0.AND.VM2.EQ.0.)GOTO 18
1216.      VM1=VNYYC+VMYM
1217.      V1=1/PI/VM1
1218.      V2=1/PI/VM2
1219.      ALPHA=I*T1
1220.      IF(A.EQ.0..AND.VM2.NE.0.)GOTO 14
1221.      GAMA=ALPHA+BETA
1222.      IF(A.NE.0..AND.VM2.NE.0.) GOTO 19
1223.      12 SOX=XL
1224.      GOTO 1111
1225.      13 SOX=0.5*XL
1226.      GOTO 1111
1227.      18 SOX=0.5*XL*COS(BETA)
1228.      GOTO 1111
1229.      14 SOX=0.5*(SIN(ALPHA)*(V1+V2))*(-1)**(IP+2)
1230.      GOTO 1111
1231.      19 SOX=0.5*(SIN(GAMA)*(-1)**(IP+2)-SIN(BETA))*(V1+V2)
1232.      GOTO 1111
1233.      C**** TYPE #2. CIRCLE/CIRCULAR CYLINDER
1234.      20 SOX=0.0
1235.      I=WN(3,NWN,NVOL)
1236.      IP=WMO(3,MWM,ISUR)
1237.      IF(IABS(I-IP).GT.0) GOTO 1111
1238.      RO=WMO(1,MWM,ISUR)
1239.      RA=(WN(1,NWN,NVOL)**2/CO**2-(WN(4,NWN,NVOL)*PI
1240.      & /VNODC(4,3,NVOL))**2)
1241.      RA=(ABS(RA))**0.5
1242.      S=0.0
1243.      E=ONODC(2,1,ISUR)
1244.      SOX=BES(I,1.0,C.0,1.0,0.0,RO,RA,S,E)
1245.      GOTO 1111
1246.      C**** TYPE #3. ANNULOUS OF CONCENTRIC CIRCLES/CIRCULAR CYLINDER
1247.      30 SOX=0.0
1248.      I=WN(3,NWN,NVOL)
1249.      IP=WMO(3,MWM,ISUR)
1250.      IF(IABS(I-IP).GT.0) GOTO 1111
1251.      RO=WMO(1,MWM,ISUR)
1252.      RA=(WN(1,NWN,NVOL)**2/CO**2-(WN(4,NWN,NVOL)*PI

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1253.      & /VNODC(4,3,NVOL)**2)
1254.      RA=ABS(RA)**0.5
1255.      S=ONODC(3,2,ISUR)
1256.      E=ONODC(2,1,ISUR)
1257.      SOX=BES(I,1.0,0.0,1.0,0.0,RO,RA,S,E)-BJP(E*RO,I)/BYP(E*RO,I)
1258.      & *BES(I,0.,1.,1.,0.,RO,RA,S,E)
1259.      GOTO 1111
1260.  C**** TYPE #4. ANNULOUS OF CONCENTRIC CIRCLES/ANNULOUS OF CONCENTRIC
1261.  C*      CYLINDERS
1262.      40 SOX=0.0
1263.      I=WN(3,NWN,NVOL)
1264.      IP=WMO(3,MWM,ISUR)
1265.      IF(IABS(I-IP).GT.0) GOTO 1111
1266.      RO=WMO(1,MWM,ISUR)
1267.      RA=(WN(1,NWN,NVOL)**2/CO**2-(WN(4,NWN,NVOL)*PI
1268.      & /VNODC(4,3,NVOL)**2)
1269.      RA=ABS(RA)**0.5
1270.      S=ONODC(3,2,ISUR)
1271.      E=ONODC(2,1,ISUR)
1272.      C1=BJP(RO*E,I)/BYP(RO*E,I)
1273.      C2=BJP(RA*VNODC(2,1,ISUR),I)/BYP(RA*VNODC(2,1,ISUR),I)
1274.      SOX=BES(I,1.0,0.,1.0,0.,RO,RA,S,E)-C1*BES(I,0.,1.,1.,0.,RO,
1275.      & RA,S,E)-C2*BES(I,1.0,0.0,0.0,1.0,RO,RA,S,E)+C1*C2*
1276.      & BES(I,1.,0.,0.,1.,RO,RA,S,E)
1277.      GOTO 1111
1278.      1111 RETURN
1279.  C*****
1280.      FUNCTION SOY(LTYP,ISUR,NVOL,IA,CF,NWN,MWM)
1281.  C*
1282.  C*
1283.  C* SOY ANALYTICALLY CALCULATES THE Y-COMPONENT OF LNM FOR COMPONENT
1284.  C* MODE SYNTHESIS (IN MULCV). LNM IS ALWAYS CALCULATED OVER THE
1285.  C* ENTIRE OPENING.
1286.  C*
1287.  C*
1288.  C* ISUR: OPENING NUMBER
1289.  C* NVOL: VOLUME NUMBER
1290.  C* LTYP: OPENING/VOLUME INTEGRATION TYPE
1291.  C* IA: ARRAY OF INTEGER CONSTANTS
1292.  C* CF: ARRAY OF REAL CONSTANTS FOR ANALYTIC INTEGRATION
1293.  C*
1294.      DIMENSION IA(3),CF(4,3)
1295.      ISUR=ISUR
1296.  C*
1297.      GOTO(10,20,30,40),LTYP
1298.  C**** TYPE #1. RETANGLE/RETANGULAR PARALLOPJPED
1299.      10 CONTINUE
1300.      I=WN(IA(2),NWN,NVOL)
1301.      JP=WMO(3,MWM,ISUR)
1302.      A=CF(2,2)
1303.      A1=CF(3,2)
1304.      YL=CF(4,2)
1305.      IF(IABS(YL-A1).GT.ZERO) GOTO 17
1306.      IF(I+JP.EQ.0)GOTO 11
1307.      IF(I-JP.NE.0) GOTO 15
1308.      IF(I-JP.EQ.0) GOTO 16
1309.      11 SOY=YL

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1310.      GOTO 1111
1311.      15  SOY=0.0
1312.      GOTO 1111
1313.      16  SOY=0.5*YL
1314.      GOTO 1111
1315.      17  YCM1=A1-YL
1316.      T1=PI*YL/A1
1317.      TT1=PI*A/A1
1318.      VMMYM=JP/YL
1319.      VNYYC=I/A1
1320.      IF(I+JP.EQ.0) GOTO 12
1321.      VM2=VNYYC-VMMYM
1322.      IF(ABS(VM2).LT.ZERO)VM2=C.0
1323.      IF(A.EQ.0..AND.VM2.EQ.0.) GOTO 13
1324.      BETA=I*TT1
1325.      IF(A.NE.0.C.AND.VM2.EQ.0.)GOTO 18
1326.      VM1=VNYYC+VMMYM
1327.      V1=1/PI/VM1
1328.      V2=1/PI/VM2
1329.      ALPHA=I*T1
1330.      IF(A.EQ.0..AND.VM2.NE.0.)GOTO 14
1331.      GAMA=ALPHA+BETA
1332.      IF(A.NE.0..AND.VM2.NE.0.) GOTO 19
1333.      12  SOY=YL
1334.      GOTO 1111
1335.      13  SOY=0.5*YL
1336.      GOTO 1111
1337.      18  SOY=0.5*YL*COS(BETA)
1338.      GOTO 1111
1339.      14  SOY=0.5*(SIN(ALPHA)*(V1+V2))*(-1)**(JP+2)
1340.      GOTO 1111
1341.      19  SOY=0.5*(SIN(GAMA)*(-1)**(JP+2)-SIN(BETA))*(V1+V2)
1342.      GOTO 1111
1343.      C*** OPENING/VOLUME TYPES 2,3,4 HAVE SAME THATA RESULTS
1344.      20  CONTINUE
1345.      30  CONTINUE
1346.      40  CONTINUE
1347.      I=WN(3,NWN,NVOL)
1348.      JP=WMO(3,MWM,ISUR)
1349.      IF(I.EQ.JP.AND.JP.NE.0)SOY=PI
1350.      IF(IABS(I-JP).GT.0)SOY=0.0
1351.      IF(I.EQ.JP.AND.JP.EQ.0)SOY=PI*2.
1352.      GOTO 1111
1353.      1111 RETURN
1354.      C*****
1355.      FUNCTION SOZ(LTYP,ISUR,NVOL,IA,CF,NWN,MWM)
1356.      C* SOZ ANALYTICALLY CALCULATES THE Z-COMPONENT OF LNM FOR COMPONENT
1357.      C* MODE SYNTHESIS (IN MULCV). LNM IS ALWAYS CALCULATED OVER THE
1358.      C* ENTIRE OPENING.
1359.      C*
1360.      C*
1361.      C* ISUR: OPENING NUMBER
1362.      C* NVOL: VOLUME NUMBER
1363.      C* LTYP: OPENING/VOLUME INTEGRATION TYPE
1364.      C* IA: ARRAY OF INTEGER CONSTANTS
1365.      C* CF: ARRAY OF REAL CONSTANTS FOR ANALYTIC INTEGRATION
1366.      C*
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1367.      DIMENSION IA(3),CF(4,3)
1368.      C*
1369.      GOTO(10,20,30,40),LTP
1370.      C*** TYPE #1. RETANGLE/RETANGULAR PARALLOPJED
1371.      10 CONTINUE
1372.      K=WN(IA(3),NWN,NVOL)
1373.      SOZ=ISUR*MWM
1374.      SOZ=COS(K*PI*(-CF(2,3)/CF(3,3)))
1375.      GOTO 1111
1376.      C*** OPENING/VOLUME TYPE 2,3,4 COMBINATIONS ALL REQUIRE SAME SOZ
1377.      20 CONTINUE
1378.      30 CONTINUE
1379.      40 CONTINUE
1380.      K=WN(4,NWN,NVOL)
1381.      SOZ=COS(K*PI*CF(1,1)/CF(1,2))
1382.      GOTO 1111
1383.      1111 RETURN
1384.      C*****
1385.      FUNCTION BES(J,A,B,C,D,AL,BT,S,F)
1386.      DIMENSION U(8)
1387.      C*
1388.      C* INTEGRATION OF (A*BJ(AL*X,J)+B*BY(AL*X,J))*(C*BJ(BT*X,J)+
1389.      C* D*BY(BT*X,J))*X OVER X FROM S TO F
1390.      C*
1391.      BES=0.0
1392.      ALX=AL*F
1393.      BTX=BT*F
1394.      DO 1 I=1,8
1395.      1 U(I)=0.0
1396.      IF(A.EQ.0.0) GOTO 10
1397.      U(1)=BJ(ALX,J)
1398.      U(2)=BJP(ALX,J)
1399.      10 IF(B.EQ.0.0) GOTO 11
1400.      U(3)=BY(ALX,J)
1401.      U(4)=BYP(ALX,J)
1402.      11 IF(AL.EQ.BT) GOTO 13
1403.      IF(C.EQ.0.0) GOTO 12
1404.      U(5)=BJ(BTX,J)
1405.      U(6)=BJP(BTX,J)
1406.      12 IF(D.EQ.0.0) GOTO 13
1407.      U(7)=BY(BTX,J)
1408.      U(8)=BYP(BTX,J)
1409.      13 CONTINUE
1410.      IF(BT.EQ.AL) BESU=F**2/2*((U(2)+U(4))**2+(1-J**2/ALX**2)*
1411.      6 (U(1)+U(3))**2)
1412.      IF(BT.NE.AL) BESU=F/(BT**2-AL**2)*((AL*(U(5)+U(7))*(U(2)+U(4)))
1413.      6 -(BT*(U(1)+U(3))*(U(6)+U(8))))
1414.      IF(S.EQ.0.0) GOTO 20
1415.      ALX=AL*S
1416.      BTX=BT*S
1417.      IF(A.EQ.0.0) GOTO 14
1418.      U(1)=BJ(ALX,J)
1419.      U(2)=BJP(ALX,J)
1420.      14 IF(B.EQ.0.0) GOTO 15
1421.      U(3)=BY(ALX,J)
1422.      U(4)=BYP(ALX,J)
1423.      15 IF(AL.EQ.BT) GOTO 17

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1424.      IF(C.EQ.D.D) GOTO 16
1425.      U(5)=BJ(BTX,J)
1426.      U(6)=BJP(BTX,J)
1427.      16 IF(D.EQ.D.C) GOTO 17
1428.      U(7)=BY(BTX,J)
1429.      U(8)=BYP(BTX,J)
1430.      17 CONTINUE
1431.      IF(BT.EQ.AL) BES=S**2/2*((U(2)+U(4))**2+(1-J**2/ALX**2)*
1432.      & (U(1)+U(3))**2)
1433.      IF(AL.NE.BT) BES=S/(BT**2-AL**2)*((AL*(U(5)+U(7))*(U(2)+U(4)))
1434.      & -(BT*(U(1)+U(3))*(U(6)+U(8))))
1435.      20 BES=BESU-BES
1436.      RETURN
1437.      C*
1438.      C*****
1439.      SUBROUTINE ANJAFS(IS)
1440.      C*
1441.      C*
1442.      C* ANALYTIC CALCULATION OF JOINT ACCEPTANCE IN FORM REQUIRED BY
1443.      C* THE EXTERNAL PRESSURE FIELD TYPE. MODE SHAPE DESCRIPTION IS GIVEN
1444.      C* BY FOURIER SERIES.
1445.      C*
1446.      C*
1447.      IR=NSTOR(IS)
1448.      READ(12,IR)BPQ
1449.      DO 200 MWM=1,NM(IS)
1450.      DO 100 NOB=L BAND,MBAND
1451.      RJA(NOB)=0.0
1452.      IF(CENTF(NOB)-WM(1,MWM).GT.BNDWM(NOB,1))GOTO 100
1453.      IF(WM(1,MWM)-CENTF(NOB).GT.BNDWM(NOB,2))GOTO 100
1454.      GOTO(10,20,30),IPF(IS)
1455.      C*** PRESSURE FIELD TYPE #1. REVERBERANT
1456.      10 BX=SNODC(2,1,IS)*CENTF(NOB)/PI/CO
1457.      BY=SNODC(3,2,IS)*CENTF(NOB)/PI/CO
1458.      DO 13 M=1,MX
1459.      DO 12 MP=1,MP
1460.      CALL RVBJA(VJP,BX,M,MP,PI)
1461.      IF(VJP.EQ.D.D)GO TO 12
1462.      DO 11 N=1,NX
1463.      DO 11 NP=1,NP
1464.      CALL RVBJA(VJQ,BY,N,NP,PI)
1465.      VI=VI+VJP*VJQ*BPQ(M,N,MWM)*BPQ(MP,NP,MWM)
1466.      11 CONTINUE
1467.      12 CONTINUE
1468.      13 CONTINUE
1469.      GOTO 90
1470.      C*** PRESSURE FIELD TYPE #2. AERODYNAMIC TURBULENCE
1471.      20 AX=EX(1,IS)
1472.      AY=EX(3,IS)
1473.      BX=SNODC(2,1,IS)*CENTF(NOB)/PI/CO*EX(2,IS)
1474.      BY=SNODC(3,2,IS)*CENTF(NOB)/PI/CO*EX(4,IS)
1475.      DO 23 M=1,MX
1476.      DO 22 MP=1,MP
1477.      CALL ATJA(VJP,AX,BX,M,MP,PI)
1478.      IF(VJP.EQ.D.D) GOTO 22
1479.      DO 21 N=1,NX
1480.      DO 21 NP=1,NP

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1481.      CALL ATJA(VJQ,AY,BY,N,NP,PI)
1482.      VI=VI+VJP* VJQ*BPQ(M,N,MWM)*BPQ(MP,NP,MWM)
1483.      21  CONTINUE
1484.      22  CONTINUE
1485.      23  CONTINUE
1486.      GOTO 90
1487.      C****  PRESSURE FIELD TYPE #3. PLANE WAVE FIELD
1488.      30  BX=SNODC(2,1,IS)*CENTF(NOBI)/PI/CO*COS(EX(1,IS))
1489.      BY=SNODC(3,2,IS)*CENTF(NOBI)/PI/CO*COS(EX(1,IS))
1490.      DO 33 M=1,MX
1491.      DO 32 MP=1,MX
1492.      CALL PWJA(VJP,BX,M,MP,PI)
1493.      IF(VJP.EQ.C.O)GOTO 32
1494.      DO 31 N=1,NX
1495.      DO 31 NP=1,NX
1496.      CALL PWJA(VJQ,BY,N,NP,PI)
1497.      VI=VI+VJP*VJQ*BPQ(M,N,MWM)*BPQ(MP,NP,MWM)
1498.      31  CONTINUE
1499.      32  CONTINUE
1500.      33  CONTINUE
1501.      GOTO 90
1502.      C****
1503.      90  RJA(NOBI)=VI/AMN(MWM,1)**2
1504.      100 CONTINUE
1505.      IR=(NSTOR(IS)-1)*NSMT+MWM
1506.      WRITE(L10*IR)RJA
1507.      200 CONTINUE
1508.      1111 RETURN
1509.      C*****
1510.      SUBROUTINE ANJASS(IS)
1511.      C*
1512.      C*  ANALYTIC CALCULATION OF JA FOR A SIMPLE SIN*SIN MODE SHAPE
1513.      C*  (SURFACE TYPE #2 AND TYPE #7 AND TYPE #8)
1514.      IR=NSTOR(IS)
1515.      IF(ISTYP(ISC).EQ.7)READ(L12*IR)BPQ
1516.      DO 200 MWM=1,NM(IS)
1517.      M=NINT(WM(2,MWM))
1518.      MP=M
1519.      N=NINT(WM(3,MWM))
1520.      NP=N
1521.      DO 100 NOBI=LBAND,MBAND
1522.      BX=SNODC(2,1,IS)*CENTF(NOBI)/PI/CO
1523.      BY=SNODC(3,2,IS)*CENTF(NOBI)/PI/CO
1524.      IF(ISTYP(IS).NE.7)GOTO 5
1525.      BX=BPQ(1,6,MWM)*CENTF(NOBI)/PI/CO
1526.      BY=BPQ(1,7,MWM)*CENTF(NOBI)/PI/CO
1527.      5  CONTINUE
1528.      RJA(NOBI)=C.O
1529.      GOTO (10,20,30),IPF(IS)
1530.      C****  PRESSURE FIELD TYPE #1. REVERBERANT
1531.      10  CALL RVBJA(VJP,BX,M,MP,PI)
1532.      CALL RVBJA(VJQ,BY,N,NP,PI)
1533.      GOTO 90
1534.      C****  PRESSURE FIELD TYPE #2. AERODYNAMIC TURBULENCE
1535.      20  AX=EX(1,IS)
1536.      AY=EX(3,IS)
1537.      CALL ATJA(VJP,AX,BX,M,MP,PI)

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1538.      CALL ATJA(VJQ,AY,BY,N,NP,PI)
1539.      GOTO 90
1540.      C**** PRESSURE FIELD TYPE #3. PLANE WAVE
1541.      30 BX=BX*COS(EX(1,IS))
1542.      BY=BY*COS(EX(1,IS))
1543.      CALL PWJA(VJP,BX,M,MP,PI)
1544.      CALL PWJA(VJQ,BY,N,NP,PI)
1545.      GOTO 90
1546.      C*****
1547.      90 RJA(NOB)=VJP*VJQ/AMN(MWM,1)**2
1548.      IF(ISTYP(IS).EQ.7)RJA(NOB)=RJA(NOB)*(BPQ(1,6,MWM)*BPQ(1,7,MWM))
1549.      & **2/AREA(IS)**2
1550.      100 CONTINUE
1551.      IR=(NSTOR(IS)-1)*NSMT+MWM
1552.      WRITE(L10,IR)RJA
1553.      200 CONTINUE
1554.      RETURN
1555.      C*****
1556.      SUBROUTINE PFCAL(IS)
1557.      C*
1558.      C* CALCULATE THE JOINT ACCEPTANCE OF A POINT FORCE EXCITATION
1559.      DO 200 MWM=1,NM(IS)
1560.      RJA(1)=(SIM(EX(1,IS),EX(2,IS),IS,MWM))**2/AMN(MWM,1)**2/
1561.      & AREA(IS)**2
1562.      DO 100 NOB=LBAND,MBAND
1563.      100 RJA(NOB)=RJA(1)
1564.      IR=(NSTOR(IS)-1)*NSMT+MWM
1565.      WRITE(L10,IR)RJA
1566.      200 CONTINUE
1567.      RETURN
1568.      C*****
1569.      SUBROUTINE RVBJA(VJP,B,J,K,PI)
1570.      C*
1571.      C*
1572.      C* SPECIAL ROUTINE FOR ANALYTIC CALCULATION OF REVERBERANT
1573.      C* FIELD JOINT ACCEPTANCE WITH SIN*SIN MODE SHAPE
1574.      C*
1575.      C*
1576.      DOUBLE PRECISION E,F,G,H,DPI
1577.      DPI=3.14159265D0
1578.      VJP=0.0
1579.      IF((-1)**(J+K).LT.0)GOTO 1111
1580.      E=DPI*DBLE((B+J))
1581.      F=DPI*DBLE((B-J))
1582.      G=DPI*DBLE((B+K))
1583.      H=DPI*DBLE((B-K))
1584.      IF(J.EQ.K) GO TO 200
1585.      T1=1.0/(PI**2*B*(K**2-J**2))
1586.      VJP=T1*(K*(CIN(E)-CIN(F))-J*(CIN(G)-CIN(H)))
1587.      GOTO 1111
1588.      C 200 VJP=(1./12.*J*PI**2*B)*(CIN(E)-CIN(F))+(1./2./PI/B)*(SI(E)+SI(F))
1589.      200 CONTINUE
1590.      T1A=(1./12.*J*PI**2*B)
1591.      T1B=(CIN(E)-CIN(F))
1592.      T1=T1A*T1B
1593.      T2=(1./2./PI/B)*(SI(E)+SI(F))
1594.      T3=(1./PI**2/(J**2-B**2))*(1.-(-1)**J*COS(PI*B))

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1595.      VJP=T1+T2+T3
1596.      1111 RETURN
1597.      FUNCTION SI(X)
1598.      DOUBLE PRECISION X,A,A1,FC,PR
1599.      A=0.000
1600.      FC=1.00
1601.      DO 10 N=0,40
1602.      PR=DFLOAT(2*N+1)
1603.      FC=FC*DFLOAT((2*N)*(2*N+1))
1604.      IF(FC.EQ.0.000)FC=1.000
1605.      A1=DFLOAT((-1)**N)*X**PR/PR/FC
1606.      A=A+A1
1607.      IF(ABS(A1).LE.1.00-5 ) GO TO 20
1608.      10 CONTINUE
1609.      20 CONTINUE
1610.      SI=REAL(A)
1611.      RETURN
1612.      FUNCTION CIN(X)
1613.      DOUBLE PRECISION X,A,A1,FC,PR
1614.      A=0.000
1615.      FC=1.00
1616.      DO 10 N=1,40
1617.      PR=DFLOAT(2*N)
1618.      FC=FC*DFLOAT((2*N-1)*(2*N))
1619.      A1=DFLOAT((-1)*(-1)**N)*X**PR/PR/FC
1620.      A=A+A1
1621.      IF(ABS(A1).LE.1.00-5) GOTO 20
1622.      10 CONTINUE
1623.      20 CONTINUE
1624.      CIN=REAL(A)
1625.      RETURN
1626.      C*****
1627.      SUBROUTINE PWJA(VJP,B,J,K,PI)
1628.      C*
1629.      C* ANALYTIC CALCULATION OF SIN*SIN MODE SHAPE AND PROGRESSIVE
1630.      C* WAVE ACOUSTIC FIELD JOINT ACCEPTANCE
1631.      VJP=0.0
1632.      IF((-1)**(J+K).LT.0) GOTO 1111
1633.      VJP=2.*J*K/PI**2/(J**2-B**2)/(K**2-B**2)*(1-(-1)**J*COS(PI*B))
1634.      1111 RETURN
1635.      C*****
1636.      SUBROUTINE ATJA(VJP,AL,B,J,K,PI)
1637.      C* SPECIAL ROUTINE FOR THE ANALYTIC CALCULATION OF PROGRESSIVE
1638.      C* WAVE FIELD JOINT ACCEPTANCE WITH SIN*SIN MODE SHAPE
1639.      C*
1640.      B1=(2./(J**2+K**2))**0.5*B
1641.      BJ1=B/J
1642.      DJ=((AL**2+1)*BJ1**2+1)**2-4*BJ1**2
1643.      IF(J.EQ.K) GO TO 10
1644.      BK=B/K
1645.      DK=((AL**2+1)*BK**2+1)**2-4*BK**2
1646.      AJK=(J**2+K**2)**2/(2.*PI**2*J**3*K**3*DJ*DK)*(((AL**2-1)*B1**2+1)
1647.      **2-4*(AL*B1**2)**2-(FLOAT((K**2-J**2))/(K**2+J**2))**2)
1648.      BJK=2.*(J**2+K**2)**2/(PI**2*J**3*K**3*DJ*DK)*AL*B1**2*((AL**2-1)
1649.      **2+1)
1650.      VJP=AJK*(1-(-1)**J*EXP(-PI*AL*B)*COS(PI*B))+BJK*((-1)**J*EXP(-PI*
1651.      AL*B)*SIN(PI*B))

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1652.      GOTO 1111
1653.      10 AJ=2./((J*PI)**2*DJ**2)*(((AL**2-1)*BJ1**2+1)**2-4*(AL*BJ1**2)**2)
1654.      EJ=8./((J*PI)**2/DJ**2*AL*BJ1**2*((AL**2-1)*BJ1**2+1)
1655.      CJ=1./((J*PI)/DJ*AL*BJ1*((AL**2+1)*BJ1**2+1)
1656.      VJP=AJ*(1-(-1)**J*EXP(-PI*AL*B)*COS(PI*B))+EJ*(-1)**J*EXP(-PI*AL*B
1657.      1)*SIN(PI*B)+CJ
1658.      1111 RETURN
1659.      C*****
1660.      C*****
1661.      FUNCTION BJ(X,N)
1662.      C      COMPUTES THE J BESSEL FUNCTION OF THE FIRST KIND FOR A
1663.      C      GIVEN ARGUMENT X, AND A GIVEN ORDER N.
1664.      C      X=ARGUMENT OF THE J BESSEL FUNCTION
1665.      C      N=THE ORDER OF THE J BESSEL FUNCTION
1666.      C      D=REQUIRED ACCURACY
1667.      C      BJ=THE RESULTANT BESSEL FUNCTION
1668.      C      DOUBLE PRECISION XD,Z,ZZ,VAR,VAL,SUM,TOTAL,BLJ
1669.      C      DEFINE BSLJ(TOTP,TOTQ,ARG)=SQRT(2./(PI*X))*
1670.      C      (TOTP*SIN(ARG)+TOTQ*COS(ARG))
1671.      XD=DBLE(X)
1672.      IF(X.GT.10.)GOTO 250
1673.      IF(N.GT.55) GOTO 300
1674.      IF(X.EQ.0.) GOTO 30
1675.      M=57-N
1676.      Z=1.000
1677.      ZZ=XD*XD
1678.      SUM=0.000
1679.      TOTAL=0.000
1680.      BJ1=1.000
1681.      DO 10 I=1,M
1682.      K=I-1
1683.      VAR=2.00**(2*K+N)
1684.      TOTAL=SUM+EJ1*Z/FAC(I)/FAC(I+N)/VAR
1685.      IF(TOTAL.EQ.0.00)GOTO 5
1686.      VAL=SUM/TOTAL
1687.      IF(VAL.GT.DN.AND.VAL.LT.UP) GOTO 20
1688.      5 BJ1=-BJ1
1689.      Z=Z*ZZ
1690.      SUM=TOTAL
1691.      10 CONTINUE
1692.      20 BLJ=XD**N*TOTAL
1693.      BJ=REAL(BLJ)
1694.      RETURN
1695.      30 IF(N.GT.0) GOTO 40
1696.      BJ=1.0
1697.      RETURN
1698.      40 BJ=0.0
1699.      RETURN
1700.      C**** USE ASYMTOTIC SERIES SOLUTION
1701.      250 IF(N.GT.8) GOTO 275
1702.      CALL PSQS(N,X,TOTP,TOTQ,ARG)
1703.      BJ=BSLJ(TOTP,TOTQ,ARG)
1704.      RETURN
1705.      C**** USE SYMTOTIC SERIES THE RECURSION WHEN N>8
1706.      275 CALL PSQS(8,X,TOTP,TOTQ,ARG)
1707.      BLJN=BSLJ(TOTP,TOTQ,ARG)
1708.      CALL PSQS(7,X,TOTP,TOTQ,ARG)

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1709.      BLJNM1=BSLJ(TOTP,TOTQ,ARG)
1710.      CALL RECUR(N,X,BLJN,BLJNM1,BJ)
1711.      RETURN
1712.      300 BJ=0.0
1713.      RETURN
1714.      C*****
1715.      C*****
1716.      FUNCTION BY(X,N)
1717.      C*
1718.      C* CALCULATES THE NEUMANN FUNCTION
1719.      C*
1720.      DOUBLE PRECISION XD,TOTAL,CUM,SUM,Z,ZZ,DIV,VAL,BLY,BLJ
1721.      DEFINE BSLY(TOTP,TOTQ,ARG)=SQRT(2./(PI*X))*
1722.      & (TOTP*SIN(ARG)+TOTQ*COS(ARG))
1723.      XD=DBLE(X)
1724.      IF(X.GT.1C.)GOTO 250
1725.      IF(N.GT.55) GOTO 300
1726.      C*** CALCULATE BY SERIES DEFINITION
1727.      IF(X.EQ.0.)GOTO 50
1728.      TOTAL=0.00
1729.      CUM=0.00
1730.      SUM=0.00
1731.      Z=XD*XD/4.00
1732.      IF(N.EQ.0) GOTO 15
1733.      ZZ=1.00
1734.      DO 10 I=1,N
1735.      DIV=FAC(N-I+1)/FAC(I)
1736.      CUM=CUM+DIV*ZZ
1737.      ZZ=ZZ*Z
1738.      10 CONTINUE
1739.      15 ZZ=1.00
1740.      BY1=1.00
1741.      M=57-N
1742.      DO 30 I=1,M
1743.      DIV=ZZ/FAC(I)
1744.      TOTAL=SUM+(PSI(I)+PSI(I+N))*BY1*DIV/FAC(I+N)
1745.      VAL=SUM/TOTAL
1746.      IF(VAL.GT.DN.AND.VAL.LT.UP) GOTO 40
1747.      20 BY1=-BY1
1748.      ZZ=ZZ*Z
1749.      SUM=TOTAL
1750.      30 CONTINUE
1751.      40 DIV=((2.00/XD)**N)/DPI
1752.      BLJ=DBLE(BJ(X,N))
1753.      BLY=(-DIV)*CUM+(2.00/DPI)*DLOG(XD/2.00)*BLJ-(((XD/2.00)**N)/PI)
1754.      & * TOTAL
1755.      BY=REAL(BLY)
1756.      RETURN
1757.      50 BY=-1.0E35
1758.      RETURN
1759.      60 BY=1.0E35
1760.      RETURN
1761.      C*** USE ASYMTOTIC SERIES SOLUTION
1762.      250 IF(N.GT.8) GOTO 275
1763.      CALL PSQS(N,X,TOTP,TOTQ,ARG)
1764.      BY=BSLY(TOTP,TOTQ,ARG)
1765.      RETURN

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1766. C*** USE ASYMTOTIC SERIES THEN RECURSION FOR N>8
1767. 275 CALL PSQS(8,X,TOTP,TOTQ,ARG)
1768. BLYN=BSLY(TOTP,TOTQ,ARG)
1769. CALL PSQS(7,X,TOTP,TOTQ,ARG)
1770. BLYN1=BSLY(TOTP,TOTQ,ARG)
1771. CALL RECUP(N,X,BLYN,BLYNM1,BY)
1772. RETURN
1773. 300 BY=-1.35
1774. RETURN
1775. C*****
1776. SUBROUTINE PSQS(N,X,TOTP,TOTQ,ARG)
1777. DOUBLE PRECISION ATEX,BJ1,TRMP,TRMQ,SUMP,SUMQ,RJ,RK,U,VAL,TP,TQ,XC
1778. XD=DBLE(X)
1779. U=4.00*N*N
1780. ATEX=8.00*X
1781. BJ1=-1.00
1782. TRMP=1.00
1783. SUMP=1.000
1784. SUMQ=0.00
1785. RJ=1.00
1786. DO 10 M=2,56,2
1787. RK=RJ+2.00
1788. TRMQ=TRMP*(U-RJ*RJ)/ATEX
1789. TRMP=TRMQ*(U-RK*RK)/ATEX
1790. TP=SUMP+BJ1*TRMP/FAC(M+1)
1791. BJ1=-BJ1
1792. TQ=SUMQ+BJ1*TRMQ/FAC(M)
1793. IF(TQ.EQ.0.00)GOTO 5
1794. VAL=SUMQ/TQ
1795. IF(VAL.GT.CN.AND.VAL.LT.UP) GOTO 20
1796. 5 SUMQ=TQ
1797. SUMP=TP
1798. RJ=RK+2.00
1799. 10 CONTINUE
1800. 20 ARG=REAL(X-DPI*(N/2.00+0.2500))
1801. TOTP=REAL(TP)
1802. TOTQ=REAL(TQ)
1803. RETURN
1804. C*****
1805. SUBROUTINE RECUR(N,X,BSLN,BSLNM1,BSL)
1806. QTNT=2./X
1807. K=N-1
1808. DO 10 I=8,K
1809. BSLNP1=QTNT*I*BSLN-BSLNM1
1810. BSLNM1=BSLN
1811. BSLN=BSLNP1
1812. 10 CONTINUE
1813. BSL=BSLN
1814. RETURN
1815. C*****
1816. FUNCTION BI(X,N)
1817. C COMPUTES THE I BESSEL FUNCTION(MODIFIED) FOR A GIVEN ARGUMENT
1818. C AND ORDER.
1819. C X=ARGUMENT OF THE I BESSEL FUNCTION
1820. C N=ORDER OF THE I BESSEL FUNCTION
1821. C BI=RESULTANT
1822. C IER=RESULTANT ERROR CODE

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1823.  C      IER=0  NO ERROR
1824.  C      IER=1  N IS NEGATIVE
1825.  C      IER=2  X IS NEGATIVE
1826.  C      N MUST BE GREATER THAN OR EQUAL TO ZERO
1827.  C
1828.  C      CHECK FOR ERRORS IN N AND X AND EXIT CONDITIONAL
1829.  C
1830.      IER=0
1831.      BI=1.0
1832.      IF(N)150,15,10
1833.  10      IF(X)160,20,20
1834.  15      IF(X)160,17,20
1835.  17      RETURN
1836.  C
1837.  C      DEFINE TOLERANCE
1838.  C
1839.  20      TOL=1.E-4
1840.  C
1841.  C      IF ARGUMENT GT 12 AND GT N, USE ASYMPTOTIC FORM
1842.  C
1843.      IF(X-12.)40,40,30
1844.  30      IF(X-FLOAT(N))40,40,110
1845.  C
1846.  C      COMPUT FIRST TERM OF SERIES AND SET INITIAL VALUE OF THE SUM
1847.  C
1848.  40      XX=X/2.
1849.      FACTN=1.0
1850.      IF(N-1)70,70,50
1851.  50      DO 60 I=2,N
1852.      FI=I
1853.  60      FACTN=FACTN*FI
1854.  70      TERM=(XX**N)/FACTN
1855.      BI=TERM
1856.      XX=XX*XX
1857.  C
1858.  C      COMPUTE UP TO 30 TERMS, STOPPING WHEN ABS(TERM) LE ABS(SUM OF
1859.  C      TERM TIMES TOLERANCE
1860.  C
1861.      DO 90 K=1,30
1862.      IF(ABS(TERM)-ABS(BI*TOL))100,100,80
1863.  80      FK=K*(N+K)
1864.      TERM=TERM*(XX/FK)
1865.  90      BI=BI+TERM
1866.  C
1867.  C      RETURN BI AS ANSWER
1868.  C
1869.  100     RETURN
1870.  C
1871.  C      X GT 12 AND X GT N, SO USE ASYMPTOTIC APPROXIMATION
1872.  C
1873.  110     FNT=4*N*N
1874.      XX=1./(8.*X)
1875.      TERM=1.
1876.      BI=1.
1877.      DO 130 K=1,30
1878.      IF(ABS(TERM)-ABS(TOL*BI))140,140,120
1879.  120     FK=(2*K-1)**2

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1880.      TERM=TERM*XX*(FK-FNT)/FLOAT(M)
1881.      130  BI=BI+TERM
1882.      140  PI=3.141592653
1883.      BI=BI*EXP(X)/SQRT(2.*PI*X)
1884.      GO TO 100
1885.      150  IER=1
1886.      GO TO 100
1887.      160  IER=2
1888.      GO TO 100
1889.      C*****
1890.      FUNCTION BJP(X,N)
1891.      C*
1892.      C* CALCULATE THE DERIVATIVE OF THE BESSEL FUNCTION OF THE FIRST
1893.      C* KIND OF ORDER N
1894.      C*
1895.      IF(N.EQ.0)BJP=-1.0*BJ(X,N+1)
1896.      IF(N.GT.0)BJp=0.5*(BJ(X,N-1)-BJ(X,N+1))
1897.      1111 RETURN
1898.      C*****
1899.      FUNCTION BYP(X,N)
1900.      C*
1901.      C* DERIVATIVE OF THE BESSEL FUNCTION OF THE SECOND KIND OF ORDER N
1902.      C*
1903.      IF(N.EQ.0)BYP=-1.0*BY(X,N+1)
1904.      IF(N.GT.0)BYp=0.5*(BY(X,N-1)-BY(X,N+1))
1905.      1111 RETURN
1906.      C*****
1907.      FUNCTION BIP(X,N)
1908.      C*
1909.      C* DERIVATIVE OF THE MODIFIED BESSEL FUNCTION OF THE FIRST KIND
1910.      IF(N.EQ.0)BIP=-1.0*BI(X,N+1)
1911.      IF(N.GT.0)BIP=0.5*(BI(X,N-1)-BI(X,N+1))
1912.      RETURN
1913.      END

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FTN 10125 IBANK 3680 DBANK 299 COMMON

,S XX.MDLPRM,XX.

1GR1A 12/14/83-18:39(12,)

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1. C*****
2. SUBROUTINE MDLPRM(WNMC,VMNPA,ZANN,RMN,RJA,WM,NM,SPL,CENTF,ISTYP,
3. *NSTOR,NAMT,NPROBN,NFS,NTAPE,NSMX,NMS,NSMT,
4. *PREF,NAM,NV,NS,NTOB,ZMDATA,LBAND,MBAND,L4,L8,L9,L10)
5. C*****
6. DIMENSION WNMC(NAM),VMNPA(NAM),ZANN(NAM),RMN(NAM,NV),
7. *WM(3,NSMX),NM(NMS),SPL(NTOB),CENTF(NTOB),NSTOR(NS),
8. *ZMDATA(NTOB,NMS),RJA(NTOB),ISTYP(NS)
9. IOUT=6
10. DO 15 I=1,NTOB
11. 15 CENTF(I)=CENTF(I)/6.283185
12. DO 20 I=1,NAM
13. 20 WNMC(I)=WNMC(I)/6.283185
14. WRITE(IOUT,1) NTAPE,NPROBN
15. WRITE(IOUT,2)
16. READ(L4*NPROBN) RMN
17. DO 100 I=1,NAM
18. 100 WRITE(IOUT,3) WNMC(I),VMNPA(I),ZANN(I)
19. WRITE(IOUT,4)
20. WRITE(IOUT,5)
21. DO 200 I=1,NAM
22. WRITE(IOUT,6) WNMC(I)
23. DO 150 J=1,NV
24. 150 WRITE(IOUT,7) J,RMN(I,J)
25. 200 CONTINUE
26. SUB=0.0
27. WRITE(IOUT,8)
28. WRITE(IOUT,9)
29. DO 300 I=1,NMS
30. IF(ISTYP(I).EQ.0)GOTO 300
31. IR=3*NFS+NSTOR(I)
32. READ(L8*IR,ERR=111)SPL
33. IR= NSTOR(I)
34. READ(L9*IR,ERR=111) WM
35. WRITE(IOUT,10)I,NTAPE,NSTOR(I)
36. WRITE(IOUT,11) PREF
37. DO 250 J=LBAND,MBAND
38. 250 WRITE(IOUT,12) CENTF(J),SPL(J), ZMDATA(J,I)
39. DO 280 J=1,NM(I)
40. WRITE(IOUT,13)WM(1,J)/6.28315
41. IR=(NSTOR(I)-1)*NSMT+J
42. READ(L10*IR,ERR=111)RJA
43. DO 275 K=LBAND,MBAND
44. WRITE(IOUT,14)CENTF(K),RJA(K)
45. 275 CONTINUE
46. 280 CONTINUE
47. 300 CONTINUE
48. DO 350 I=1,NTOB
49. 350 CENTF(I)=CENTF(I)*6.28315
50. DO 360 I=1,NAM
51. 360 WNMC(I)=WNMC(I)*6.28315
52. 1 FORMAT(43X,'ACOUSTIC PARAMETERS',SX,'TAPE# ',I3,', PROBLEM# '
53. *,I3/43X,'*****')
54. 2 FORMAT(//25X,'CAVITY NATURAL FREQUENCIES (HZ) GENERALIZED MASS
55. *,11X,'DAMPING (LOSS FACTOR)'/25X,'*****')

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56.      A',5X,'*****',11X,'*****')
57.      3 FORMAT(35X,E10.5,19X,E10.5,19X,E10.5)
58.      4 FORMAT(////25X,'DISTRIBUTION OF ACOUSTIC ENERGY')
59.      5 FORMAT(/,25X,'CAVITY NATURAL FREQUENCIES (HZ)',10X,'VOLUME',24X,
60.      *   'RMN'/25X,'*****',10X,'*****',21X,
61.      A'*****')
62.      6 FORMAT(35X,E10.5)
63.      7 FORMAT(67X,I3,23X,E10.5)
64.      8 FORMAT(/////56X,'STRUCTURAL PARAMETERS',/56X,
65.      A'*****')
66.      9 FORMAT(/46X,'MODAL ANALYSIS'/46X,'*****')
67.      10 FORMAT(/44X,'* SURFACE ',I3,' (SAVED ON TAPE ',I3,' SURFACE ',
68.      A I3,')')
69.      11 FORMAT(///62X,'EXTERNAL SPL'/39X,'FREQUENCY (HZ)',6X,
70.      A'(DB,REF ',E10.5,')',9X,'ZMDATA'/39X,'*****',6X,
71.      A'*****',7X,'*****')
72.      12 FORMAT(41X,E10.5,12X,E10.5,12X,E10.5)
73.      13 FORMAT(/39X,'NATURAL FREQUENCY (HZ)',7X,'BAND CENTER FREQUENCY'
74.      &,7X,'JOINT ACCEPTANCE'/39X,E10.5,29X,'*****',7X,
75.      &'*****')
76.      14 FORMAT(79X,E10.5,7X,E11.5)
77.      NAMT=NAMT
78.      111 RETURN
79.      END

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FTN 321 IBANK 534 DBANK

..S XX.CALC,XX.

10R1A 12/14/83-18:39(42,)

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1. C*****
2. SUBROUTINE CALC(ANS,ANSS,BNS,BNSS,WNMC,ZANN,VMNPA,RMN,NM,AREA,WM,
3. &VLNM,SPL,RJA,ZM,CENTF,NSTOR,NV,NAM,NS,NMS,NSMX,NFS,NSMT,LBAND
4. &MBAND,NTOB,NPROBN,BW,ZERO,PREF,VOL,RO,CO,PI,L7,L8,L9,L10,IOUT,
5. &SPLT,ISTYP,NST)
6. C*
7. C*
8. C*   ANS: SPACE AVERAGED, BAND AVERAGED PRESSURE OVER WHOLE
9. C*   MULTIPLE CAVITY SYSTEM
10. C*  ANSS: SPACE AVERAGED, BAND AVERAGED PRESSURE OVER EACH
11. C*  SUBVOLUME OF THE MULTIPLE CAVITY SYSTEM
12. C*  BNS: SPACE AVERAGED, BAND AVERAGED PRESSURE OVER WHOLE
13. C*  MULTIPLE CAVITY SYSTEM DUE ONLY TO SURFACE ISUR
14. C*  BNSS: SPACE AVERAGED, BAND AVERAGED PRESSURE OVER EACH
15. C*  SUBVOLUME OF THE MULTIPLE CAVITY SYSTEM DUE ONLY TO
16. C*  SURFACE ISUR
17. C*
18. C*
19. DIMENSION WNMC(NAM),ZANN(NAM),VMNPA(NAM),RMN(NAM,NV),VLNM(NAM),
20. *NM(NMS),AREA(NS),SPL(NTOB),ANS(NTOB),ANSS(NTOB,NV),WM(3,NSMX),
21. *CENTF(NTOB),NSTOR(NS),ZM(NSMX),BNSS(NTOB,NV),BNS(NTOB)
22. DIMENSION RJA(NTOB),SPLT(NTOB),ISTYP(NS)
23. WRITE(IOUT,9)
24. DO 20 I=1,MBAND
25.   ANS(I)=0.0
26.   DO 20 J=1,NMS
27.     20 ANSS(I,J)=0.0
28. C*
29.   DO 800 ISUR=1,NMS
30.     IF(ISTYP(ISUR).EQ.0)GOTO 800
31. C*
32.     FCT=RO**2*CO**4*AREA(ISUR)**4/VOL**2/2.
33.     DO 30 I=1,MBAND
34.       BNS(I)=0.0
35.       DO 30 J=1,NMS
36.         30 BNSS(I,J)=0.0
37.       IR=NSTOR(ISUR)
38.       READ(L9*IR)WM
39.       IR=NFS+NSTOR(ISUR)
40.       READ(L9*IR)(ZM(J),J=1,NM(ISUR))
41.       WRITE(6,*)ZM
42.       IR=3*NFS+NSTOR(ISUR)
43.       READ(L8*IR) SPL
44. C
45. C
46. C
47. C
48. C
49. C
50. C
51.   DO 40 I=1,NTOB
52.     40 SPL(I)=PREF**2*10.**(SPL(I)/10.0)
53. C*
54. C*
55.   DO 500 MM=1,NM(ISUR)

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56. C*
57. C*
58. IR=((ISUR-1)*NSMT*MWM+NSMT*NST*(NPROBN-1))
59. READ(L7*IR)(VLNM(I),I=1,NAM)
60. IR=(INSTOR(ISUR)-1)*NSMT*MWM
61. READ(L10*IR)RJA
62. DO 250 NWN=1,NAM
63. C****
64. IF(ABS(VLNM(NWN)).LT.ZERO) GOTO 250
65. C****
66. FAC=VLNM(NWN)**2/VMNPA(NWN)
67. CALL COEF(A,B,C,D,E,F,G1,H,A1,P1,A2,P2,MWM,NWN)
68. DO 100 I=LBAND,MBAND
69. W1=CENF(I)-BW*CENF(I)
70. W2=CENF(I)+BW*CENF(I)
71. SQM=RJA(I)*FAC*FCT*SPL(I)/(2.*BW*CENF(I))
72. AN1=SQM*VINT(A,B,C,D,E,F,G1,H,A1,P1,A2,P2,W1,W2)
73. ANS(I)=ANS(I)+AN1
74. BNS(I)=BNS(I)+AN1
75. C**** CALCULATE SABAP OVER EACH SUBVOLUME OF THE SYSTEM
76. DO 50 NVOL=1,NV
77. ANSS(I,NVOL)=ANSS(I,NVOL)+AN1*RMN(NWN,NVOL)
78. BNSS(I,NVOL)=BNSS(I,NVOL)+AN1*RMN(NWN,NVOL)
79. 50 CONTINUE
80. 100 CONTINUE
81. 250 CONTINUE
82. 500 CONTINUE
83. C***** WRITE OUT SABAP DUE TO SURFACE 'ISUR' *****
84. WRITE(IOUT,10) ISUR
85. DO 570 NVOL=1,NV
86. WRITE(IOUT,2) NVOL
87. WRITE(IOUT,3) PREF
88. DO 560 I=LBAND,MBAND
89. VAL= 10.*ALOG10(BNSS(I,NVOL)/PREF**2)
90. FQ=CENF(I)/2./PI
91. WRITE(IOUT,5) FQ,VAL
92. 560 CONTINUE
93. 570 CONTINUE
94. WRITE(IOUT,8)
95. WRITE(IOUT,3) PREF
96. TOT=0.0
97. DO 580 I=LBAND,MBAND
98. VAL= 10.*ALOG10(BNS(I)/PREF**2)
99. FQ=CENF(I)/2./PI
100. WRITE(IOUT,5) FQ,VAL
101. TOT=TOT+BNS(I)
102. 580 CONTINUE
103. TOT=10.*ALOG10(TOT/PREF**2)
104. WRITE(IOUT,7) TOT
105. C****
106. 800 CONTINUE
107. C**** CALCULATE SABAP DUE TO ALL THE SURFACES IN DB
108. C***** AND MAKE CORRECTION FOR RERADIATION
109. DO 803 NOB=1,NTOB
110. 803 SPLT(NOB)=0.0
111. AT=0.0
112. DO 804 IS=1,NMS

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113.      IF(ISTYP(IS).EQ.0) GOTO 804
114.      AT=AT+AREA(IS)
115.      804 CONTINUE
116.      DO 806 IS=1,NMS
117.      IF(ISTYP(IS).EQ.0) GOTO 806
118.      IR=3*NFS+NSTOR(IS)
119.      READ(18*IR)SPL
120.      DO 805 NOB=LBAND,MBAND
121.      SPL(NOB)=PREF**2*10.**(SPL(NOB)/10.)
122.      805 SPLT(NOB)=AREA(IS)/AT*SPL(NOB)+SPLT(NOB)
123.      806 CONTINUE
124.
125.
126.      2 FORMAT(///44X,'VOLUME - ',I3/44X,'*****')
127.      3 FORMAT(80X,'PRESSURE'/43X,'CENTER FREQUENCY (HZ)',1CX,'(DB,REF& ',
128.      AE11.5,')'/40X,'*****',8X,
129.      A'*****')
130.      5 FORMAT(48X,E11.5,21X,E11.5)
131.      7 FORMAT(1,50X,'OVERALL',22X,E11.5)
132.      8 FORMAT(///44X,'SYSTEM AVERAGE'/44X,'*****')
133.      9 FORMAT(8(1),56X,'PRELIMINARY RESULTS OF'/55X,'CLASSICAL MODAL ANAL
134.      AYSIS'/44X,'SPACE-AVERAGED,BAND-AVERAGED PRESSURE SQUARED'/44X,
135.      A'*****')
136.      10 FORMAT(///44X,'NOISE DUE TO MOTION OF SURFACE - ',I3)
137.      CALL MDLRES
138.      1111 RETURN
139.      C*****
140.      SUBROUTINE COEF(AA2,BB2,CC2,DD2,EE2,FF2,GG2,HH2,ALPHA1,PHI1,
141.      *ALPHA2,PHI2,MWM,NWN)
142.      DOUBLE PRECISION CA(4,5),DET
143.      COMPLEX X,Y
144.      A8=W(1,MWM)
145.      B8=Z(MWM)
146.      E8=WMC(NWN)
147.      D8=ZANN(NWN)
148.      IF (A8.EQ.E8) E8=E8+5.0
149.      G=4*A8**2*B8**2-2*A8**2
150.      ALPHA=-G/2
151.      PHI=((4*A8**4-G**2)**0.5)/2
152.      X=CMPLX(ALPHA,PHI)
153.      Y=CSQRT(X)
154.      ALPHA1=REAL(Y)
155.      PHI1=AIMAG(Y)
156.      G=4.*E8**2*D8**2-2.*E8**2
157.      ALPHA=-G/2
158.      PHI=((4*E8**4-G**2)**0.5)/2
159.      X=CMPLX(ALPHA,PHI)
160.      Y=CSQRT(X)
161.      ALPHA2=REAL(Y)
162.      PHI2=AIMAG(Y)
163.      S1=ALPHA1**2+PHI1**2
164.      S2=ALPHA2**2+PHI2**2
165.      CA(1,5)=0.00
166.      CA(2,5)=0.00
167.      CA(3,5)=1.00
168.      CA(4,5)=0.00
169.      CA(1,1)=DFLOAT(2*S1*S2**2)

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170.      CA(1,2)=DFLOAT(0.000)
171.      CA(1,3)=DFLOAT(2*S1**2*S2)
172.      CA(1,4)=DFLOAT(C.0)
173.      CA(2,1)=DFLOAT(2*(S2**2+2*S1*S2-4*ALPHA2**2*S1))
174.      CA(2,2)=DFLOAT(4*ALPHA1*S2**2)
175.      CA(2,3)=DFLOAT(2*(S1**2+2*S1*S2-4*ALPHA1**2*S2))
176.      CA(2,4)=DFLOAT(4*ALPHA2*S1**2)
177.      CA(3,1)=DFLOAT(2*(2*S2+S1-4*ALPHA2**2))
178.      CA(3,2)=DFLOAT(2*(4*ALPHA1*S2-8*ALPHA1*ALPHA2**2))
179.      CA(3,3)=DFLOAT(2*(2*S1+S2-4*ALPHA1**2))
180.      CA(3,4)=DFLOAT(2*(4*ALPHA2*S1-8*ALPHA1**2*ALPHA2))
181.      CA(4,1)=DFLOAT(2.0)
182.      CA(4,2)=DFLOAT(4*ALPHA1)
183.      CA(4,3)=DFLOAT(2.0)
184.      CA(4,4)=DFLOAT(4*ALPHA2)
185.      CALL DPINV(CA,4,1,4,DET)
186.      BBZ=REAL(CA(1,5))
187.      CCZ=REAL(CA(2,5))
188.      FFZ=REAL(CA(3,5))
189.      GGZ=REAL(CA(4,5))
190.      DDZ=BBZ
191.      AAZ=-CCZ
192.      EEZ=-GGZ
193.      HHZ=FFZ
194.      RETURN
195.      C*****
196.      FUNCTION VINT(AAZ,BBZ,CCZ,DDZ,EEZ,FFZ,GGZ,HHZ,ALPHA1,PHI1,
197.      *ALPHA2,PHI2,W1,W2)
198.      TERM1=(AAZ/2)*ALOG(W2**2+2*ALPHA1*W2+ALPHA1**2+PHI1**2)+((BBZ-
199.      *ALPHA1*AAZ)/PHI1)*ATAN((W2+ALPHA1)/PHI1)-((AAZ/2)*ALOG(W1**2+2*
200.      *ALPHA1*W1+ALPHA1**2+PHI1**2)+((BBZ-ALPHA1*AAZ)/PHI1)*ATAN((W1+
201.      *ALPHA1)/PHI1))
202.      TERM2=(CCZ/2)*ALOG(W2**2-2*ALPHA1*W2+ALPHA1**2+PHI1**2)+((CCZ*
203.      *ALPHA1+DDZ)/PHI1)*ATAN((W2-ALPHA1)/PHI1)-((CCZ/2)*ALOG(W1**2-2*
204.      *ALPHA1*W1+ALPHA1**2+PHI1**2)+((CCZ*ALPHA1+DDZ)/PHI1)*ATAN((W1-
205.      *ALPHA1)/PHI1))
206.      TERM3=(EEZ/2)*ALOG(W2**2+2*ALPHA2*W2+ALPHA2**2+PHI2**2)+((FFZ-
207.      *ALPHA2*EEZ)/PHI2)*ATAN((W2+ALPHA2)/PHI2)-((EEZ/2)*ALOG(W1**2+2*
208.      *ALPHA2*W1+ALPHA2**2+PHI2**2)+((FFZ-ALPHA2*EEZ)/PHI2)*ATAN((W1+
209.      *ALPHA2)/PHI2))
210.      TERM4=(GGZ/2)*ALOG(W2**2-2*ALPHA2*W2+ALPHA2**2+PHI2**2)+((GGZ*
211.      *ALPHA2+HHZ)/PHI2)*ATAN((W2-ALPHA2)/PHI2)-((GGZ/2)*ALOG(W1**2-2*
212.      *ALPHA2*W1+ALPHA2**2+PHI2**2)+((GGZ*ALPHA2+HHZ)/PHI2)*ATAN((W1-
213.      *ALPHA2)/PHI2))
214.      VINT=(TERM1+TERM2+TERM3+TERM4)
215.      111 RETURN
216.      C*****
217.      SUBROUTINE MDLRES
218.      C*
219.      C*
220.      C* MDLRES OUTPUTS THE FINAL RESULTS OF THE REQUESTED MODAL ANALYSIS
221.      C*
222.      100 WRITE(10UT,1)
223.      TOT=0.0
224.      DO 120 NVOL=1,NV
225.      WRITE(10UT,2) NVOL
226.      WRITE(10UT,3) PREF

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227.      WRITE(IOUT,4)
228.      DO 110 NOB=LBAND,MBAND
229.      ANSS(NOB,NVOL)=ANSS(NOB,NVOL)/(1+ANSS(NOB,NVOL)/SPLT(NOB))
230.      TOT=ANSS(NOB,NVOL)+TOT
231.      VAL=10.*ALOG10(ANSS(NOB,NVOL)/PREF**2)
232.      FQ=CENF(NOB)/2./PI
233.      WRITE(IOUT,5) FQ,VAL
234.      110 CONTINUE
235.      TOT=10.*ALOG10(TOT/PREF**2)
236.      WRITE(IOUT,7) TOT
237.      120 CONTINUE
238.      TOT=1.0
239.      WRITE(IOUT,8)
240.      WRITE(IOUT,3) PREF
241.      WRITE(IOUT,4)
242.      DO 130 NOB=LBAND,MBAND
243.      ANS(NOB)=ANS(NOB)/(1+ANS(NOB)/SPLT(NOB))
244.      TOT=ANS(NOB)+TOT
245.      VAL=10.*ALOG10(ANS(NOB)/PREF**2)
246.      FQ=CENF(NOB)/2./PI
247.      WRITE(IOUT,5) FQ,VAL
248.      130 CONTINUE
249.      TOT=10.*ALOG10(TOT/PREF**2)
250.      WRITE(IOUT,7) TOT
251.      C*****
252.      1 FORMAT(8(/),44X,'SPACE-AVERAGED,BAND-AVERAGED PRESSURE SQUARED',
253.      *44X,'*****')
254.      2 FORMAT(///44X,'VOLUME - ',I3/44X,'*****')
255.      3 FORMAT(80X,'PRESSURE'/43X,'CENTER FREQUENCY (HZ)',I2X,'(DB,REF & ',
256.      AE11.5,')'/40X,'*****',8X,
257.      A'*****')
258.      4 FORMAT(40X,'( MODAL ANALYSIS)')
259.      5 FORMAT(48X,E11.5,21X,E11.5)
260.      7 FORMAT(/,50X,'OVERALL',22X,E11.5)
261.      8 FORMAT(///44X,'SYSTEM AVERAGE'/44X,'*****')
262.      C****
263.      1111 RETURN
264.      END

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FTN 1754 IBANK 1141 DBANK

,S XX,DFCALC,XX.

10R1A 12/14/83-18:39(24,)

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1. C*****
2. SUBROUTINE DFCALC(ANS,ANSS,WNMC,ZANN,VMNPA,RMN,NM,AREA,WM,WF,WI,
3.   EVLNM,SPL,RJA,ZM,CENTF,NSTOR,NV,NSMT,NAM,NS,NMS,NSMX,NFS,ISTYP,
4.   ENWS,NTOB,NPROBN,ZERO,PREF,VOL,RO,CO,PI,NST,L7,L8,L9,L10,IOUT,BW,
5.   & TBND)
6. C*
7. C*   ANS: SPACE AVERAGED PRESSURE AT DESCRETE FREQUENCIES OVER WHOLE
8. C*   MULTIPLE CAVITY SYSTEM
9. C*   ANSS: SPACE AVERAGED PRESSURE OVER EACH SUBVOLUME OF THE MULTIPLE
10. C*   CAVITY SYSTEM
11. C*
12. C*
13.   DIMENSION WNMC(NAM),ZANN(NAM),VMNPA(NAM),RMN(NAM,NV),VLNM(NAM),
14.   *NM(NMS),AREA(NS),SPL(NTOB),ANS(NWS),ANSS(NWS,NV),WM(3,NSMX),
15.   *CENTF(NTOB),NSTOR(NS),ZM(NSMX),ISTYP(NS)
16.   DIMENSION RJA(NTOB),TBND(NWS)
17.   WF=2.*PI*WF
18.   WI=2.*PI*WI
19.   DW=(WF-WI)/NWS
20.   WRITE(IOUT,9)
21.   DO 20 I=1,NWS
22.     ANS(I)=0.0
23.     DO 20 J=1,NMS
24.       2C ANSS(I,J)=0.0
25.       DO 24 I=1,NWS
26.         DO 22 NOB=1,NTOB
27.           WL=CENTF(NOB)*(1-BW)
28.           WH=CENTF(NOB)*(1+BW)
29.           TS=WI+I*DW
30.           22 I=(TS.GT.WL.AND.TS.LT.WH)GOTO 23
31.           23 TBND(I)=NOB*1.
32.           24 CONTINUE
33.           DO 800 ISUR=1,NMS
34.             IF(ISTYP(ISUR).EQ.0)GOTO 800
35.             FCT=RO**2*CO**4*AREA(ISUR)**4/VOL**2/2.
36.             IR=NSTOR(ISUR)
37.             READ(L9*IR)WM
38.             IR= NFS+NSTOR(ISUR)
39.             READ(L9* IR)(ZM(J),J=1,NM(ISUR))
40.             IR= 3*NFS+NSTOR(ISUR)
41.             READ(L8*IP) SPL
42.             DO 25 I=1,NTOB
43.               25 SPL(I)=PREF**2*10**((SPL(I)/10.))
44.             WRITE(6,*)ZM
45.             WRITE(6,*)WM
46.             WRITE(6,*)WNMC
47.             WRITE(6,*)ZANN
48.             DO 500 MWM=1,NM(ISUR)
49.               IR=((ISUR-1)*NSMT+MWM+NSMT*NST*(NPROBN-1))
50.               READ(L7*IR)VLNM
51.               IR=(NSTOR(ISUR)-1)*NSMT+MWM
52.               READ(L10*IR)RJA
53.               DO 250 NWN=1,NAM
54.                 C***
55.                 IF(ABS(VLNM(NWN)).LT.ZERO) GOTO 250

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56. C****
57.     FAC=VLNM(NWN)**2/VMNPA(NWN)
58.     DO 100 I=1,NWS
59.     NOB=INT(TEND(I))
60.     SQM=RJA(NOB)*FCT*FAC*SPL(NOB)/(2*BW*CENTF(NOB))
61.     AN1=SQM*VQ(WM(1,MWM),WNMC(NWN),ZM(MWM),ZANN(NWN),I,DW)
62.     ANS(I)=ANS(I)+AN1
63. C**** CALCULATE SABAP OVER EACH SUBVOLUME OF THE SYSTEM
64.     DO 50 NVOL=1,NV
65.     ANSS(I,NVOL)=ANSS(I,NVOL)+AN1*RMN(NWN,NVOL)
66.     50 CONTINUE
67.     100 CONTINUE
68.     250 CONTINUE
69.     500 CONTINUE
70. C**** MAKE CORRECTION FOR RERADIATION THROUGH THE SURFACE AND CONVERT
71. C**** INTO PRESSURE
72.     DO 540 K=1,NWS
73.     NOB=INT(TEND(K))
74.     ANS(K)=ANS(K)/(1+ANS(K)/SPL(NOB))
75.     DO 530 NVOL=1,NV
76.     ANSS(K,NVOL)=FAC*ANSS(K,NVOL)
77.     ANSS(K,NVOL)=ANSS(K,NVOL)/(1+ANSS(K,NVOL)/SPL(NOB))
78.     530 CONTINUE
79.     540 CONTINUE
80.     800 CONTINUE
81. C***** WRITE OUT SABAP DUE TO ALL THE SURFACES *****
82.     DO 570 NVOL=1,NV
83.     WRITE(IOUT,2) NVOL
84.     WRITE(IOUT,3) PREF
85.     DO 560 I=1,NWS
86.     VAL= 10.*ALOG10(ANSS(I,NVOL)/PREF**2)
87.     FQ=(I*DW+W1)/2./PI
88.     WRITE(IOUT,5) FQ,VAL
89.     560 CONTINUE
90.     570 CONTINUE
91.     WRITE(IOUT,8)
92.     WRITE(IOUT,3) PREF
93.     TOT=0.0
94.     DO 580 I=1,NWS
95.     VAL= 10.*ALOG10(ANS(I)/PREF**2)
96.     FQ=(I*DW+W1)/2./PI
97.     WRITE(IOUT,5) FQ,VAL
98.     TOT=TOT+ANS(I)
99.     580 CONTINUE
100.    TOT=10.0*ALOG10(TOT/PREF**2)
101.    WRITE(IOUT,7) TOT
102. C****
103.    2 FORMAT(///44X,'VOLUME - ',I3/44X,'*****')
104.    3 FORMAT(80X,'PRESSURE',/43X,' FREQUENCY (HZ)',10X,'(DB,REF& ',
105.    AE10.5,')',/40X,'*****',8X,
106.    A'*****')
107.    5 FORMAT(48X,E10.5,21X,E10.5)
108.    7 FORMAT(/,50X,'OVERALL',22X,E10.5)
109.    8 FORMAT(///44X,'SYSTEM AVERAGE',/44X,'*****')
110.    9 FORMAT(8(/),56X,'PRELIMINARY RESULTS OF',/55X,'CLASSICAL MODAL ANAL
111.    AYSIS',/44X,'SPACE-AVERAGED, PRESSURE SQUARED',/44X,
112.    A'*****')

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113.      1111 RETURN
114.      C*****
115.      FUNCTION VC(SF,AF,SZ,AZ,I,DW)
116.      FRQ=I*DW*WI
117.      VQ=FRQ**4/((SF**2-FRQ**2)**2+4*SZ**2*FRQ**2*SF**2)
118.      & /((AF**2-FRQ**2)**2+4*AZ**2*FRQ**2*AF**2)
119.      RETURN
120.      END
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FTN 836 IBANK 516 DBANK

V,S XX,HFREQ,XX.

10R1A 12/14/83-18:39(47,)

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1. C*****
2. SUBROUTINE HFREQ(RJA,SPL,CENTF,AREA,AREAO,MD,ZMDATA
3. *,MASSUR,RJARV,ZNDATA,IOTYP,IGEMOV,ISV,
4. *C,NV,NV1,IHBAND,NTOB,NS,NOO,NMS,MNSS,BW,NFS,ANSS,
5. *EX,MBAND,WMH,NSDAT,NSTOR,ISEAO,IPF,NFV,NSEAC,NPFC,NPROBN,MOP,
6. *L2,L8,L13,L14)
7. C*****
8. C***** STATISTICAL ENERGY ANALYSIS *****
9. COMMON/AREA8/RO,CO,VOL,PREF,PI
10. REAL RJA(NS,NTOB),SPL(NMS,NTOB),CENTF(NTOB),AREA(NS)
11. &,ZMDATA(NMS,NTOB),RJARV(NS,NTOB),ZNDATA(NTOB,NS)
12. &,EX(NPFC,NMS)
13. DIMENSION MD(NMS,NTOB),IOTYP(NOO),AREAO(NOO),ISEAO(NMS),IPF(NMS),
14. *MASSUR(MNSS,NMS),IGEMOV(2,NS),ISV(NS),MOP(4)
15. *,ANSS(NTOB,NV),WMH(NSEAC,NTOB),NSDAT(NMS),NSTOR(NMS)
16. DOUBLE PRECISION C(NV,NV1),DET
17. CHARACTER*10 CHR
18. LAST=MBAND
19. LAST1=MBAND-2
20. C***** LOAD ACOUSTIC LOSS FACTOR FOR EACH SURFACE *****
21. IR=2*NFV+NPROBN
22. READ(L2*IR)ZNDATA
23. C**** LOAD STRUCTURAL LOSS FACTOR FOR EACH SURFACE
24. DO 20 IS=1,NMS
25. IR=2*NFS+NSTOR(IS)
26. READ(L8*IR)(ZMDATA(IS,J),J=1,NTOB)
27. 20 CONTINUE
28. C***** LOAD REFERENCE SPL *****
29. DO 30 IS=1,NMS
30. IR= 3*NFS+ NSTOR(IS)
31. READ(L8*IR)(SPL(IS,J),J=1,NTOB)
32. DO 30 J=1,NTOB
33. SPL(IS,J)=PREF**2*10.**(SPL(IS,J)/10.)
34. 30 CONTINUE
35. C***** ZERO JOINT ACCEPTANCE ARRAYS *****
36. DO 50 I=1,NS
37. DO 50 J=1,NTOB
38. RJA(I,J)=0.0
39. RJARV(I,J)=0.0
40. 50 CONTINUE
41. C**** CALL SEA CALCULATIONS
42. CALL MDEN
43. CALL CJA
44. CALL HFCAL
45. 1111 RETURN
46. C*****
47. SUBROUTINE CJA
48. DO 2000 IS=1,NMS
49. IF(ISEAO(IS).EQ.0)GOTO 2000
50. IF(NSDAT(IS).NE.0) GOTO 2000
51. IR=NSTOR(IS)
52. READ(L13*IR) WMH
53. DO 1500 K=1,2
54. DO 1000 NOB=MBAND-2,IHBAND
55. NOB1=NOB

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56.      CALL RJAEST(RAD,IS,NOB,NOB1,K)
57.      IF(K.EQ.1)RJA(IS,NOB)=RAD
58.      IF(K.EQ.2)RJARV(IS,NOB)=RAD
59.      IF(K.EQ.1.AND.IPF(IS).EQ.1)RJARV(IS,NOB)=RAD
60.      1000 CONTINUE
61.      IF(IPF(IS).EQ.1) GOTO 2000
62.      1500 CONTINUE
63.      2000 CONTINUE
64.      C**** STORE CALCULATED DATA ON TAPE
65.      DO 2050 IS=1,NMS
66.      IF(ISEAO(IS).EQ.0)GOTO 2050
67.      IF(NSDAT(IS).NE.0)GOTO 2050
68.      IR=NSTOR(IS)
69.      WRITE(L14*IR)(RJA(IS,J),J=1,NTOB)
70.      IR=NFS+NSTOR(IS)
71.      WRITE(L14*IR)(RJARV(IS,J),J=1,NTOB)
72.      2050 CONTINUE
73.      C**** LOAD PREVIOUSLY CALCULATED RJA,RJARV
74.      DO 2100 IS=1,NMS
75.      IF(ISEAO(IS).EQ.0)GOTO 2100
76.      IF(NSDAT(IS).EQ.0)GOTO 2100
77.      IR=NSDAT(IS)
78.      READ(L14*IR)(RJA(IS,J),J=1,NTOB)
79.      IR=NFS+NSDAT(IS)
80.      READ(L14*IR)(RJARV(IS,J),J=1,NTOB)
81.      2100 CONTINUE
82.      C**** ASSIGN JOINT ACCEPTANCE TO EACH SUBSURFACE IN DIRECT PROPORTION
83.      C**** TO SURFACE AREA RATIO
84.      DO 4000 IS=1,NMS
85.      IF(ISEAO(IS).EQ.0)GOTO 4000
86.      DO 3000 I=1,MNSS
87.      ISUR=MASSUR(I,IS)
88.      IF(ISUR.EQ.IS) GOTO 4000
89.      DO 2500 NOB=MBAND,IHBAND
90.      RJARV(ISUR,NOB)=AREA(ISUR)/AREA(IS)*RJARV(IS,NOB)
91.      2500 RJA(ISUR,NOB)=AREA(ISUR)/AREA(IS)*RJA(IS,NOB)
92.      3000 CONTINUE
93.      4000 CONTINUE
94.      1111 RETURN
95.      C*****
96.      C***** HIGH FREQUENCY CALCULATIONS *****
97.      C*****
98.      SUBROUTINE HFCAL
99.      DO 5000 NOB=MBAND,IHBAND
100.      MDL=0
101.      DO 25 IS=1,NMS
102.      25 IF(MD(IS,NOB).GT.0)MDL=MD(IS,NOB)
103.      IF(MDL.EQ.0)GOTO 5000
104.      DO 50 I=1,NV
105.      DO 50 J=1,NV1
106.      50 C(I,J)=0.00
107.      C***** FILL THE C MATRIX *****
108.      DO 1000 NVOL=1,NV
109.      WRITE(6,*)NV
110.      CHR='COT'
111.      WRITE(6,*)CHR
112.      C**** CALCULATE THE POWER TRANSFERRED OUT OF THE VOLUME THROUGH
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113. C**** THE STRUCTURAL WALLS ADJACENT TO THE VOLUME.
114. IF(MOP(3).EQ.1)GOTO 100
115. DO 100 IS=1,NMS
116. IF(ISEAO(IS).EQ.0)GOTO 100
117. DO 90 I=1,MNSS
118. ISUR=MASSUR(I,IS)
119. IF(ISUR.EQ.0) GO TO 100
120. IF(ISV(ISUR).NE.NVOL) GO TO 90
121. C(NVOL,NVOL)= C(NVOL,NVOL) + DFLOAT(COT(IS,ISUR,NOB))
122. 90 CONTINUE
123. 100 CONTINUE
124. C**** CALCULATE THE POWER TRANSFERRED OUT OF THE SUBVOLUME THROUGH
125. C**** THE OPENINGS
126. DO 200 ISUR=1,N00
127. IF(IGEMOV(1,ISUR).EQ.NVOL.OR.IGEMOV(2,ISUR).EQ.NVOL)C(NVOL,NVOL)=
128. *C(NVOL,NVOL) +DFLOAT(CVT(ISUR,NOB))
129. 200 CONTINUE
130. C**** CALCULATE THE POWER ABSORBED BY THE WALLS OF THE SUBVOLUME
131. CHR='CBS'
132. WRITE(6,*)CHR
133. DO 300 ISUR=1,Ns
134. IF(ISEAO(ISUR).EQ.0)GOTO 300
135. IF(ISV(ISUR).NE.NVOL) GO TO 300
136. C(NVOL,NVOL)= C(NVOL,NVOL) + DFLOAT(CBS(ISUR,NOB))
137. 300 CONTINUE
138. C**** CALCULATE THE POWER TRANSFERRED INTO THE SUBVOLUME FROM OTHER
139. C**** SUBVOLUMES
140. DO 500 IVOL=1,NV
141. DO 400 ISUR=1,N00
142. IF(IGEMOV(1,ISUR).EQ.NVOL.AND.IGEMOV(2,ISUR).EQ.IVOL)GO TO 350
143. IF(IGEMOV(2,ISUR).EQ.NVOL.AND.IGEMOV(1,ISUR).EQ.IVOL)GO TO 350
144. GO TO 400
145. 350 C(NVOL,IVOL)= C(NVOL,IVOL)-DFLOAT(CVT(ISUR,NOB))
146. 400 CONTINUE
147. 500 CONTINUE
148. 1000 CONTINUE
149. C**** CALCULATE THE POWER TRANSFERRED INTO THE SUBVOLUME THROUGH THE
150. C**** STRUCTURAL WALLS ADJACENT TO THAT SUBVOLUME
151. DO 1100 I=1,NV
152. 1100 C(I,NV1)=0.0
153. CHR='WIN'
154. WRITE(6,*)CHR
155. DO 2000 NVOL=1,NV
156. DO 1500 IS=1,NMS
157. IF(ISEAO(IS).EQ.0)GOTO 1500
158. DO 1400 I=1,MNSS
159. ISUR=MASSUR(I,IS)
160. IF(ISUR.EQ.0) GO TO 1500
161. IF(ISV(ISUR).NE.NVOL) GO TO 1500
162. C(NVOL,NV1)= C(NVOL,NV1)+DFLOAT(SPL(IS,NOB))* DFLOAT(WIN(IS,ISUR,
163. &NOB))/DFLOAT(2.*BW*CENTF(NOB))
164. 1400 CONTINUE
165. 1500 CONTINUE
166. 2000 CONTINUE
167. C**** SOLVE EQUATIONS AND STORE RESULTS IN APPROPRIATE ARRAYS
168. WRITE(6,*)C,NOB
169. M=1

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170.      IF(NV.GT.1)CALL DPINV(C,NV,M,NV,DET)
171.      IF(NV.EQ.1)C(1,NV1)=C(1,NV1)/C(1,1)
172.      WRITE(6,*)10.D0*DLOG10(C(1,NV1)/DFLOAT(PREF)**2)
173.      DO 2100 I=1,NV
174.      C(I,NV1)=10.D0*DLOG10(C(I,NV1)/DFLOAT(PREF)**2)
175.      2100 ANSS(NOBI,I)= REAL(C(I,NV1))
176.      WRITE(6,*)C(1,NV1)
177.      5000 CONTINUE
178.      RETURN
179.      C*****
180.      FUNCTION WIN(IS,ISUR,NOB)
181.      C*
182.      C* CALCULATE POWER FLOW INTO SUBVOLUME THROUGH THE STRUCTURAL WALLS
183.      C*
184.      RN=C.O
185.      DO 10 J=1,2
186.      G=-2.O*CENTF(NOBI-J)
187.      A=CENTF(NOBI-J)**4*(1+4.O*ZMDATA(IS,NOBI-J)**2)
188.      PHI=0.5*(4.O*A-G**2)**0.5
189.      WR=CENTF(NOBI-J)
190.      AL=-G/2.O
191.      CALL VINTE(VIN,NOBI,AL,PHI,B,WR)
192.      10 RN=RN+2.*VIN*RJA(ISUR,NOBI-J)*RJARV(ISUR,NOBI-J)*MD(IS,NOBI-J)
193.      WIN=(RO*AREA(ISUR)**4/4.O/PI/CO)*
194.      & (RN+MD(IS,NOBI)*RJA(ISUR,NOBI)*RJARV(ISUR,NOBI)*PI*CENTF(NOBI)/
195.      & (2.*ZMDATA(IS,NOBI)))
196.      RN=RN*(RO*AREA(ISUR)**4/4.O/PI/CO)
197.      WRITE(6,*)IS,ISUR,NOBI,MD(IS,NOBI),RN,WIN
198.      RETURN
199.      C*****
200.      FUNCTION COT(IS,ISUR,NOB)
201.      C*
202.      C* CALCULATE THE POWER FLOW OUT OF THE SUBVOLUMES THROUGH THE WALLS
203.      C*
204.      COT=PI*AREA(ISUR)**2*MD(IS,NOBI)*RJARV(ISUR,NOBI)
205.      WRITE(6,*)IS,ISUR,NOBI,MD(IS,NOBI),COT
206.      RETURN
207.      C*****
208.      FUNCTION CBS(ISUR,NOB)
209.      CBS= AREA(ISUR)*ZNDATA(NOBI,ISUR)/4.O/RO/CO
210.      WRITE(6,*)ISUR,NOBI,CBS
211.      RETURN
212.      C*****
213.      FUNCTION CVT(ISUR,NOB)
214.      D= (4.O*AREA0(ISUR)/PI)**0.5
215.      WVN=CENTF(NOBI)/CO
216.      CVT= AREA0(ISUR)/4.O/RO/CO*COND(D,WVN,ISUR)
217.      RETURN
218.      C*****
219.      FUNCTION COND(D,WVN,ISUR)
220.      CM= D*WVN
221.      IF(IOTYP(ISUR).EQ.1) GO TO 10
222.      IF(CM.LE.1.44) THA= (D*WVN)**2/8.O
223.      IF(CM.GT.1.44.AND.CM.LT.3.557)THA=0.35*CM-0.245
224.      IF(CM.GE.3.557) THA=1.O
225.      IF(CM.LE.1.626) XX=CM**4./3./PI
226.      IF(CM.GT.1.626.AND.CM.LE.3.433) XX=0.69

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227.      IF(CM.GT.3.443.AND.CM.LT.5.4644) XX=1.4625-0.225*CM
228.      IF(CM.GE.5.4644) XX=4./PI/CM
229.      COND= THA/(THA**2.+XX**2.)
230.      RETURN
231.      1C IF(CM.LE.0.8367) THA= CM**2./16.0
232.      IF(CM.GT.0.8367.AND.CM.LE.5.3165) THA= 0.1852* CM-0.1112
233.      IF(CM.GT.5.3165.AND.CM.LT.20.0) THA= 0.005*CM+0.9
234.      IF(CM.GE.20.) THA=1.0
235.      IF(CM.LE.2.121) XX=CM*8./9./PI
236.      IF(CM.GT.2.121.AND.CM.LE.4.2) XX=0.6
237.      IF(CM.GT.4.2.AND.CM.LT.6.602) XX= 0.9746-0.0892*CM
238.      IF(CM.GE.6.602) XX=8.0/PI/CM
239.      COND= THA/(THA**2.+XX**2.)
240.      RETURN
241.      C*****
242.      SUBROUTINE VINTE(VIN,NOB,ALPHA1,PHI1,G,WR)
243.      COMPLEX X,Y
244.      W1=CENF(NOB)*(1-BW)
245.      W2=CENF(NOB)*(1+BW)
246.      X=CMPLX(ALPHA1,PHI1)
247.      Y=CSQRT(X)
248.      ALPHA1=REAL(Y)
249.      PHI1=AIMAG(Y)
250.      AAZ=(G-WR**4/(ALPHA1**2+PHI1**2))/(4*ALPHA1)
251.      BBZ=-WR**4/2/(ALPHA1**2+PHI1**2)
252.      CCZ=-AAZ
253.      DDZ=BBZ
254.      TERM1=(AAZ/2)*ALOG(W2**2+2*ALPHA1*W2+ALPHA1**2+PHI1**2)+((BBZ-
255.      *ALPHA1*AAZ)/PHI1)*ATAN((W2+ALPHA1)/PHI1)-((AAZ/2)*ALOG(W1**2+2*
256.      *ALPHA1*W1+ALPHA1**2+PHI1**2)+((BBZ-ALPHA1*AAZ)/PHI1)*ATAN((W1+
257.      *ALPHA1)/PHI1))
258.      TERM2=(CCZ/2)*ALOG(W2**2-2*ALPHA1*W2+ALPHA1**2+PHI1**2)+((CCZ*
259.      *ALPHA1+DDZ)/PHI1)*ATAN((W2-ALPHA1)/PHI1)-((CCZ/2)*ALOG(W1**2-2*
260.      *ALPHA1*W1+ALPHA1**2+PHI1**2)+((CCZ*ALPHA1+DDZ)/PHI1)*ATAN((W1-
261.      *ALPHA1)/PHI1))
262.      VIN=TERM1+TERM2+(W2-W1)
263.      VIN=VIN*2.
264.      RETURN
265.      C*****
266.      SUBROUTINE MDEN
267.      C*
268.      C* CALCULATE THE MODAL DENSITY OF THE SEA SURFACE
269.      DO 1000 IS=1,NMS
270.      IF(ISEAO(IS).EQ.1)GOTO 1000
271.      IF(NSDAT(IS).NE.0)GOTO 1000
272.      IR=NSTOR(IS)
273.      READ(L13*IR)WMH
274.      GOTO(10,20,30),ISEAO(IS)
275.      C**** SEA SURFACE TYPE #1. EQUIVALENT ORTHOTROPIC PANEL
276.      C* SUMS ALL MODES WITHIN EACH BAND AND CALCULATES AND AVERAGE
277.      C* M AND N INDEX FOR THE BAND
278.      10 CONTINUE
279.      LAST1=MBAND-2
280.      FAC=(WMH(1,1)*WMH(1,2))**0.5
281.      XL=WMH(1,7)
282.      YL=WMH(1,8)
283.      FACX=(WMH(1,1)/FAC)**0.5

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284.      FACY=(WMH(1,2)/FAC)**0.5
285.      FACXY=(WMH(1,1)*WMH(1,4)+WMH(1,2)* WMH(1,5)+WMH(1,3))/2.0
286.      IF(WMH(1,1).EQ.WMH(1,2)) FACXY=FAC
287.      FAC1=(FAC/WMH(1,6))**0.5*PI**2
288.      DO 19 NOB=LAST1,IHBAND
289.      WL=CENF(NOB)/FAC1*(1-BW)
290.      WH=CENF(NOB)/FAC1*(1+BW)
291.      NC=0
292.      MT=0
293.      NT=0
294.      C* THIS LOOP IS NOT INTENDED TO BE COMPLETED. THE LOOP IS CUT SHORT
295.      C* WHEN ALL MODES IN THE BAND HAVE BEEN CALCULATED.
296.      DO 17 M=1,5000
297.      DO 16 N=1,5000
298.      VAL=(FACX*(M/XL)**2+FACY*(N/YL)**2)**2+2.*(M/XL)**2*(N/YL)**2
299.      & *(FACXY/FAC-1)
300.      VAL=SQRT(VAL)
301.      IF(VAL.LT.WL)GOTO 15
302.      IF(VAL.GT.WH)GOTO 11
303.      NC=NC+1
304.      MT=MT+M
305.      NT=NT+N
306.      15 CONTINUE
307.      16 CONTINUE
308.      11 CONTINUE
309.      IF(N.GT.1)GOTO 17
310.      GOTO 18
311.      17 CONTINUE
312.      C*** CALCULATE THE AVERAGE M AND N FOR THE BAND
313.      18 CONTINUE
314.      WMH(2,NOB)=ANINT(MT*1./NC)
315.      WMH(3,NOB)=ANINT(NT*1./NC)
316.      IF((-1.)*(WMH(2,NOB)+WMH(3,NOB)).LT.0.)WMH(2,NOB)=WMH(2,NOB)+1
317.      C* THE ABOVE STATEMENT PREVENTS THE M,N INDEXES FROM HAVING
318.      C* VALUES THAT RESULT IN ZERO JOINT ACCEPTANCE.
319.      MD(IS,NOB)=NC
320.      19 CONTINUE
321.      IR=NSTOR(IS)
322.      WRITE(L13,IR)WMH
323.      GOTO 1000
324.      C*** SEA SURFACE TYPE #2. CYLINDRICAL SHELL
325.      20 CONTINUE
326.      WR=WMH(1,6)/WMH(1,1)
327.      FAC=2.*3**0.5*WMH(1,2)/WMH(1,3)
328.      DO 29 NOB=MBAND-2,IHBAND
329.      DW=2.*BW*CENF(NOB)/WR
330.      WH=CENF(NOB)/WR
331.      IF(WH.LT.0.85)MD(IS,NOB)=FAC*0.179*WH**0.5*DW+.5
332.      IF(WH.GT.0.85.AND.WH.LT.1.15) MD(IS,NOB)=FAC*0.8*DW+.5
333.      IF(WH.GT.1.15)MD(IS,NOB)=FAC*0.25*DW+.5
334.      29 CONTINUE
335.      GOTO 1000
336.      C*** SEA SURFACE TYPE #3. DATA
337.      30 CONTINUE
338.      DO 39 NOB=MEAND-2,NT08
339.      39 MD(IS,NOB)=WMH(3,NOB)*CENF(NOB)*BW*2.0
340.      GOTO 1000

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341. C****
342. 1000 CONTINUE
343. DO 1050 IS=1,NMS
344. IF(NSDAT(IS).NE.0)GOTO 1050
345. IR=2*NFS+NSTOR(IS)
346. WRITE(L14*IR)(MD(IS,I),I=1,NTOB)
347. 1050 CONTINUE
348. DO 1075 IS=1,NMS
349. IF(NSDAT(IS).EQ.0)GOTO 1075
350. IR=2*NFS+NSTOR(IS)
351. READ(L14*IR)(MD(IS,I),I=1,NTOB)
352. 1075 CONTINUE
353. 1111 RETURN
354. C*****
355. C*****
356. SUBROUTINE RJAEST(RAD,IS,NOB,NOB1,K)
357. C*
358. C* CALCULATE THE JOINT ACCEPTANCE BY EMPHIRICAL OR SEMI-EMPHIRICAL
359. C* EQUATIONS
360. C* RAD=SOLUTION
361. C* IS=SURFACE NUMBER
362. C* NOB=BAND OF INTEREST
363. C* NOB1=CONTRIBUTORY BAND
364. C* K=EXTERNAL (K=1) OR REVERBERANT (K=2) PRESSURE FIELD
365. C*
366. C**** BRANCH TO SECTION FOR PRESSURE FIELD TYPE
367. IF(K.EQ.2) GOTO 100
368. GOTO (100,200,300),IPF(IS)
369. C*****
370. C**** PRESSURE FIELD TYPE #1. REVERBERANT FIELD
371. 100 CONTINUE
372. GOTO(110,120,130),ISEAO(IS)
373. C***** SEA SURFACE TYPE #1. EQUIVALENT RETANGULAR PANEL
374. 110 CONTINUE
375. BX=WMH(1,7)*CENTF(NOB)/PI/CO
376. BY=WMH(1,8)*CENTF(NOB)/PI/CO
377. M=NINT(WMH(2,NOB1))
378. MP=M
379. N=NINT(WMH(3,NOB1))
380. NP=N
381. CALL RVBJA(VJP,BX,M,MP,PI)
382. CALL RVBJA(VJQ,BY,N,NP,PI)
383. RAD=VJP*VJQ*4.0/WMH(1,6)/AREA(IS)
384. WRITE(6,*)IS,NOB,M,N,RAD
385. GOTO 1111
386. C***** SEA SURFACE TYPE #2. CYLINDERICAL SHELL
387. 120 CONTINUE
388. BX=2./3.*(4.*PI*WMH(1,1)/(4.*PI*WMH(1,1)+2.*WMH(1,2)))
389. IF(CENTF(NOB)/WMH(1,5).GT.1.0)GOTO 121
390. RAD=BX*(PI/(2.0*RO*CO*(CENTF(NOB)/CO)**2*AREA(IS)**2))
391. & *RO*CO*AREA(IS)*(CENTF(NOB)/WMH(1,5))**0.5/(WMH(1,4)/4.)
392. WRITE(6,*)IS,NOB,RAD
393. GOTO 1111
394. 121 RAD= BX*(PI/2./(CENTF(NOB)/WMH(1,5))**2/AREA(IS))/(WMH(1,4)/4.0)
395. WRITE(6,*)IS,NOB,RAD
396. GOTO 1111
397. C***** SEA SURFACE TYPE #3. DATA

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398.      130 CONTINUE
399.      RAD=WMH(2,NOB)
400.      GOTO 1111
401.      C*****
402.      C**** PRESSURE FIELD TYPE #2. AERODYNAMIC TURBULENCE
403.      200 CONTINUE
404.      GOTO(210,220,230),ISEA0(IS)
405.      C***** SEA SURFACE TYPE #1. EQUIVALENT RETANGULAR PANEL
406.      210 CONTINUE
407.      AX=EX(1,IS)
408.      AY=EX(3,IS)
409.      BX=WMH(1,7)*CENTF(NOBI)/PI/CO
410.      BY=WMH(1,8)*CENTF(NOBI)/PI/CO
411.      M=NINT(WMH(2,NOBI))
412.      MP=M
413.      N=NINT(WMH(3,NOBI))
414.      NP=N
415.      CALL ATJA(VJP,AX,BX,M,MP,PI)
416.      CALL ATJA(VJQ,AY,BY,N,NP,PI)
417.      RAD=VJP*VJQ*4.0/WMH(1,6)/AREA(IS)
418.      GOTO 1111
419.      C***** SEA SURFACE TYPE #2. CYLINDERICAL SHELL
420.      220 CONTINUE
421.      GOTO 120
422.      C***** SEA SURFACE TYPE #3. DATA
423.      230 CONTINUE
424.      RAD=WMH(1,NOB)
425.      GOTO 1111
426.      C*****
427.      C**** PRESSURE FIELD TYPE #3. RANDOM PROGRESSIVE WAVE
428.      300 CONTINUE
429.      GOTO(310,320,330),ISEA0(IS)
430.      C* SEA SURFACE TYPE #1. EQUIVALENT RETANGULAR PANEL
431.      310 CONTINUE
432.      BX=WMH(1,7)*CENTF(NOBI)/PI/CO
433.      BY=WMH(1,8)*CENTF(NOBI)/PI/CO
434.      M=NINT(WMH(2,NOBI))
435.      MP=M
436.      N=NINT(WMH(3,NOBI))
437.      NP=N
438.      CALL PWJA(VJP,BX,M,MP,PI)
439.      CALL PWJA(VJQ,BY,N,NP,PI)
440.      RAD=VJP*VJQ*4.0/WMH(1,6)/AREA(IS)
441.      GOTO 1111
442.      C***** SEASURFACE TYPE #2. CYLINDERICAL SHELL
443.      320 CONTINUE
444.      GOTO 120
445.      C***** SEA SURFACE TYPE #3. DATA
446.      330 CONTINUE
447.      RAD=WMH(1,NOB)
448.      GOTO 1111
449.      1111 RETURN
450.      C*****
451.      C*****
452.      C*****
453.      SUBROUTINE PWJA(VJP,B,J,K,PI)
454.      C*

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455. C* ANALYTIC CALCULATION OF SIN*SIN MODE SHAPE AND PROGRESSIVE
456. C* WAVE ACOUSTIC FIELD JOINT ACCEPTANCE
457. VJP=0.0
458. IF((-1)**(J+K).LT.C) GOTO 1111
459. VJP=2.*J*K/PI**2/(J**2-B**2)/(K**2-B**2)*(1-(-1)**J*COS(PI*B))
460. 1111 RETURN
461. C*****
462. SUBROUTINE ATJA(VJP,AL,B,J,K,PI)
463. C* SPECIAL ROUTINE FOR THE ANALYTIC CALCULATION OF PROGRESSIVE
464. C* WAVE FIELD JOINT ACCEPTANCE WITH SIN*SIN MODE SHAPE
465. C*
466. B1=(2./(J**2+K**2))**0.5*B
467. BJ=B/J
468. DJ=((AL**2+1)*BJ**2+1)**2-4*BJ**2
469. IF(J.EQ.K) GO TO 10
470. BK=B/K
471. DK=((AL**2+1)*BK**2+1)**2-4*BK**2
472. AJK=(J**2+K**2)**2/(2.*PI**2*J**3*K**3*DJ*DK)*(((AL**2-1)*B1**2+1
473. ***2-4*(AL*B1**2)**2-(FLOAT((K**2-J**2)/(K**2+J**2))**2)
474. BJK=2.*(J**2+K**2)**2/(PI**2*J**3*K**3*DJ*DK)*AL*B1**2*((AL**2-1)
475. **B1**2+1)
476. VJP=AJK*(1-(-1)**J*EXP(-PI*AL*B)*COS(PI*B))+BJK*((-1)**J*EXP(-PI*
477. *AL*B)*SIN(PI*B))
478. GOTO 1111
479. 10 AJ=2./(((J*PI)**2*DJ**2)*(((AL**2-1)*BJ**2+1)**2-4*(AL*BJ**2)**2)
480. EJ=8./(J*PI)**2/DJ**2*AL*BJ**2*((AL**2-1)*BJ**2+1)
481. CJ=1./(J*PI)/DJ*AL*BJ*((AL**2+1)*BJ**2+1)
482. VJP=AJ*(1-(-1)**J*EXP(-PI*AL*B)*COS(PI*B))+EJ*(-1)**J*EXP(-PI*AL*
483. 1)*SIN(PI*B)+CJ
484. 1111 RETURN
485. SUBROUTINE RVBJA(VJP,B,J,K,PI)
486. C*
487. C*
488. C* SPECIAL ROUTINE FOR ANALYTIC CALCULATION OF REVERBERANT
489. C* FIELD JOINT ACCEPTANCE WITH SIN*SIN MODE SHAPE
490. C*
491. C*
492. DOUBLE PRECISION E,F,G,H,DPI
493. DPI=3.1415926500
494. VJP=0.0
495. IF((-1)**(J+K).LT.0)GOTO 1111
496. E=DPI*DBLE((B+J))
497. F=DPI*DBLE((B-J))
498. G=DPI*DBLE((B+K))
499. H=DPI*DBLE((B-K))
500. IF(J.EQ.K) GO TO 200
501. T1=1.0/(PI**2*B*(K**2-J**2))
502. VJP=T1*(K*(CIN(E)-CIN(F))-J*(CIN(G)-CIN(H)))
503. GOTO 1111
504. 200 CONTINUE
505. T1A=(1./(2.*J*PI**2*B))
506. T1B=(CIN(E)-CIN(F))
507. T1=T1A*T1B
508. T2=(1./2./PI/B)*(SI(E)+SI(F))
509. T3=(1./PI**2/(J**2-B**2))*(1-(-1)**J*COS(PI*B))
510. VJP=T1+T2+T3
511. 1111 RETURN

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512.      FUNCTION SI(X)
513.      DOUBLE PRECISION X,A,A1,FC,PR
514.      IF (REAL(X).GT.30.)GOTO 25
515.      A=0.000
516.      FC=1.00
517.      DO 10 N=0,40
518.      PR=DFLOAT(2*N+1)
519.      FC=FC*DFLOAT((2*N)*(2*N+1))
520.      IF (FC.EC.0.000)FC=1.000
521.      A1=DFLOAT((-1)**N)*X**PR/PR/FC
522.      A=A+A1
523.      IF (ABS(A1).LE.1.00-5 ) GO TO 20
524.      10 CONTINUE
525.      20 CONTINUE
526.      SI=REAL(A)
527.      RETURN
528.      25 SI=PI/2.0
529.      RETURN
530.      FUNCTION CIN(X)
531.      DOUBLE PRECISION X,A,A1,FC,PR
532.      IF (REAL(X).GT.30.)GOTO 25
533.      A=0.000
534.      FC=1.00
535.      DO 10 N=1,40
536.      PR=DFLOAT(2*N)
537.      FC=FC*DFLOAT((2*N-1)*(2*N))
538.      A1=DFLOAT((-1)*(-1)**N)*X**PR/PR/FC
539.      A=A+A1
540.      IF (ABS(A1).LE.1.00-5) GOTO 20
541.      10 CONTINUE
542.      20 CONTINUE
543.      CIN=REAL(A)
544.      RETURN
545.      25 CIN=0.5772157+ALOG(REAL(X))
546.      RETURN
547.      END

```

FTN 3883 IBANK 1548 DBANK 5 COMMON

1, S XX, SEAPRM, XX.

```

10R1A 12/14/83-18:39(14,)
1.      SUBROUTINE SEAPRM(RJA,RJARV,MD,ZMDATA,CENTF,SPL,
2.      MBAND,IHBAND,NTOB,NMS,NTAPE,NSTOR,ZNDATA,IOUT,NS,ISEAO)
3.      DIMENSION RJA(NS,NTOB),RJARV(NS,NTOB),
4.      MD(NMS,NTOB),ZMDATA(NMS,NTOB),CENTF(NTOB),
5.      &SPL(NMS,NTOB),NSTOR(NMS),ZNDATA(NTOB,NS),ISEAO(NMS)
6.      FAC=6.283185
7.      WRITE(IOUT,15)
8.      ISO=0
9.      DO 400 I=1,NMS
10.     IS=NSTOR(I)
11.     IF(IS.EQ.ISO)WRITE(IOUT,21)I,I-1
12.     IF(IS.EQ.ISO)GOTO 400
13.     IF(ISEAO(I).EQ.0) GOTO 400
14.     WRITE(IOUT,16) I,NTAPE,NSTOR(I)
15.     WRITE(IOUT,17)
16.     ISO=NSTOR(I)
17.     DO 350 J=MBAND,IHBAND
18.     FQ=CENTF(J)/FAC
19.     WRITE(IOUT,18)FQ,SPL(I,J),RJA(I,J),RJARV(I,J)
20.   350 CONTINUE
21.     WRITE(IOUT,19)
22.     DO 375 NOB=MBAND,IHBAND
23.     FQ=CENTF(NOB)/FAC
24.     WRITE(IOUT,20)FQ,MD(I,NOB),ZMDATA(I,NOB),ZNDATA(NOB,I)
25.   375 CONTINUE
26.   400 CONTINUE
27.     15 FORMAT(//46X,'SEA'/46X,'*****')
28.     16 FORMAT(//44X,'* SURFACE ',I3,' (SAVED ON TAPE ',I3,', SURFACE ',
29.     AI3,')')
30.     17 FORMAT(//15X,'FREQUENCY (HZ)      SPL',12X,'JA',10X,'JAREV'/
31.     A15X,'*****')
32.     18 FORMAT(17X,E10.5,4X,E10.5,4X,E10.5,4X,E10.5)
33.     19 FORMAT(//15X,'FREQUENCY (HZ)',10X,' MD ',10X,'ZMDATA',
34.     E10X,'ZNDATA'/15X,'*****',8X,
35.     E'*****',8X,'*****',8X,'*****')
36.     20 FORMAT(15X,E10.5,10X,I5,10X,E10.5,10X,E10.5)
37.     21 FORMAT(5X,'DATA FOR SURFACE - ',I3,' SAME AS FOR SURFACE - ',I3)
38.   111 RETURN
39.     END

```

FTN 213 IBANK 283 DBANK

,S XX,SEARES,XX.

CR1A 12/14/83-18:39(6,)

```

1.      SUBROUTINE SEARES(NVOL,NV,PREF,NTOB,MBAND,IHBAND,ANSS,CENTF,
2.      IOUT)
3.
4.      C*
5.      C*
6.      C* SEARES OUTPUTS THE FINAL RESULTS OF THE REQUESTED SEA ANALYSIS
7.      C*
8.      DIMENSION ANSS(NTOB,NV),CENTF(NTOB)
9.      FAC=6.283185
10.     100 WRITE(IOUT,1)
11.     DO 120 NVOL=1,NV
12.     TOT=0.0
13.     WRITE(IOUT,2) NVOL
14.     WRITE(IOUT,3) PREF
15.     DO 110 NOB=MBAND,IHBAND
16.     TOT= 10**((ANSS(NOB,NVOL)/20.0) +TOT
17.     WRITE(IOUT,5) CENTF(NOB)/FAC,ANSS(NOB,NVOL)
18.     110 CONTINUE
19.     TOT= 20.*ALOG10(TOT)
20.     WRITE(IOUT,7) TOT
21.     120 CONTINUE
22.     C*****
23.     1 FORMAT(8(/),44X,'SPACE-AVERAGED,BAND-AVERAGED PRESSURE SQUARED'/
24.     *44X,'*****')
25.     2 FORMAT(1//44X,'VOLUME - ',I3/44X,'*****')
26.     3 FORMAT(80X,'PRESSURE'/43X,'CENTER FREQUENCY (HZ)',10X,'(DB,REF & ',
27.     AE11.5,')'/40X,'*****',8X,
28.     A'*****')
29.     5 FORMAT(48X,E11.5,21X,E11.5)
30.     7 FORMAT(1/,50X,'OVERALL',22X,E11.5)
31.     C****
32.     1111 RETURN
33.     END

```

FTN 107 IBANK 170 DBANK

1,S XX.ALLOC,XX.

10R1A 12/14/83-18:40(0,)

```
1. C*****
2.     SUBROUTINE ALLOC(X,ISZ)
3. C*****
4.     ISZ= MCORF$(ISZ)-LOC(X)
5.     RETURN
6.     ENTRY IALLOC(IX,ISZ)
7.     ISZ=MCORF$(ISZ)-LOC(IX)
8.     RETURN
9.     ENTRY IFREE(MARK,IL)
10.    CALL LCORF$(IL+LOC(MARK))
11.    IL=D
12.    RETURN
13.    ENTRY FREE(ARK,IL)
14.    CALL LCORF$(IL+LOC(ARK))
15.    IL=C
16.    RETURN
17.    END
```

FTN 88 IBANK 50 DBANK

S XX.DALLOC,XX.

CR1A 12/14/83-18:40(5,)

```

1. SUBROUTINE DALLOC(D,IDIM)
2. DOUBLE PRECISION D
3. COMMON /STRG25/INUMD,ISVDA(40),ISVDX(40)
4. DATA INUMD/0/
5. IA=MCORFS(IDIM*2,3)
6. IDIM=(IA-LOC(D))/2+1
7. IX=IDIM*2+LOC(D)
8. IF(INUMD.GE.40) STOP 'DALLOC MAX'
9. INUMD=INUMD+1
10. ISVDA(INUMD)=IA
11. ISVDX(INUMD)=IX
12. RETURN
13. END

```

```

14. SUBROUTINE DFREE(D,IDIM)
15. DOUBLE PRECISION D
16. COMMON/STRG25/INUMD,ISVDA(40),ISVDX(40)
17. IX=IDIM*2+LOC(D)
18. DO 10 I=1,INUMD
19. IF(ISVDX(I).EQ.IX) THEN
20. CALL LCORFS(ISVDA(I),
21. IDIM=0
22. INUMD=INUMD-1
23. IF(I.EQ.INUMD+1)RETURN
24. IF(INUMD.EQ.0)RETURN
25. ISVDA(I)=ISVDA(INUMD+1)
26. ISVDX(I)=ISVDX(INUMD+1)
27. RETURN
28. ENDIF
29. 10 CONTINUE
30. STOP 'DFREE NO-FIND'
31. END

```

FTN 121 IBANK 48 DBANK 81 COMMON

XX REVERB, XX.

1A 12/14/83-18:40(2,)

```

1. C*****
2. SUBROUTINE REVERB(WNMC,CN,ZNDATA,ZNDI,VMNPA,CENTF,NAM,NTOB,
3. & LBAND,MBAND,NS,RO,CO,VOL,PI,NPROBN,DT,NFV,CZANN,L2,IOUT)
4. C*
5. C* CALCULATE REVERBERATION TIME OF COMPLEX CAVITY WITH
6. C* NONUNIFORM SURFACE ABSORPTION
7. C*
8. DIMENSION WNMC(NAM),CN(NS,NAM),ZNDATA(NS,NTOB),ZNDI(NS,NTOB)
9. &,VMNPA(NAM),CENTF(NAM)
10. COMPLEX CZANN(NAM),PNT,ZA
11. PRMS=CENTF(1)*PI
12. C* CALCULATE THE COMPLEX ACOUSTIC DAMPING
13. IR=NFV+NPROBN
14. READ(L2*IR,ERR=1111) CN
15. DO 10 I=1,NAM
16. 10 CZANN(I)=(0.0,0.0)
17. DO 50 ISUR=1,NS
18. IF(ISV(ISUR).EQ.0)GOTO50
19. DO 40 NOB=LBAND,MBAND
20. ZA=CMPLX(ZNDATA(ISUR,NOB),ZNDI(ISUR,NOB))
21. DO 40 I=1,NAM
22. CZANN(I)=CN(ISUR,I)*AREA(ISUR)*RO*CO**2/VOL/VMNPA(I)/ZA/2.
23. &/WNMC(I)+CZANN(I)
24. 40 CONTINUE
25. 50 CONTINUE
26. C**** CALCULATE THE OVERALL REVERBERATION TIME ASSUMING EQUAL
27. C**** POTENTIAL ENERGY IN EACH MODE AT T=0.0
28. T=0.0
29. PNT=(0.0,0.0)
30. WRITE(IOUT,55)
31. 55 FORMAT(8(/),15X,'OVERALL REVERBERATION TIME'//10X,'TIME',16X
32. &,'PRMS')
33. PRMSI=(NAM*RO**2*CO**4)**0.5
34. 60 CONTINUE
35. DO 70 NWN=1,NAM
36. T=T+DT
37. PNT=(CEXP(-CZANN(NWN)*WNMC(NWN)*T)*COS(WNMC(NWN)*T)
38. & +CZANN(NWN)*SIN(WNMC(NWN)*T))+PNT
39. PNT=PNT*CONJG(PNT)
40. PN=REAL(PNT)+PN
41. IF(NWN.EQ.1)PN=1.0
42. 70 CONTINUE
43. PRMS=RO*CO**2*PN**0.5
44. PRMS=PRMS/PRMSI
45. WRITE(IOUT,75)T,PRMS
46. 75 FORMAT(10X,F10.5,10X,F10.5)
47. IF(PRMS.GT.0.0011) GOTO 60
48. 1111 RETURN
49. END

```

383 IBANK 153 DBANK

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MCETITBINS.9#XX(1).DEL

1	QFREE L0.
2	QFREE L1.
3	QFREE L2.
4	QFREE L3.
5	QFREE L4.
6	QFREE L5.
7	QFREE L6.
8	QFREE L7.
9	QFREE L8.
10	QFREE L9.
11	QFREE L10.
12	QFREE L11.
13	QFREE L12.
14	QFREE L13.
15	QFREE L14.
16	QFREE L15.
17	QFREE L16.
18	QFREE L17.
19	QDELETE.C L0.
20	QDELETE.C L1.
21	QDELETE.C L2.
22	QDELETE.C L3.
23	QDELETE.C L4.
24	QDELETE.C L5.
25	QDELETE.C L6.
26	QDELETE.C L7.
27	QDELETE.C L8.
28	QDELETE.C L9.
29	QDELETE.C L10.
30	QDELETE.C L11.
31	QDELETE.C L12.
32	QDELETE.C L13.
33	QDELETE.C L14.
34	QDELETE.C L15.
35	QDELETE.C L16.
36	QDELETE.C L17.

EPRT.S XX.TAPIN

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MPETITBIN3_B*XX(1).TAPIN

1	@ASG.TF TAPEIN..T.10000
2	@COPY,G TAPEIN..L0.
3	@COPY,G TAPEIN..L1.
4	@COPY,G TAPEIN..L2.
5	@COPY,G TAPEIN..L3.
6	@COPY,G TAPEIN..L4.
7	@COPY,G TAPEIN..L5.
8	@COPY,G TAPEIN..L6.
9	@COPY,G TAPEIN..L7.
10	@COPY,G TAPEIN..L8.
11	@COPY,G TAPEIN..L9.
12	@COPY,G TAPEIN..L10.
13	@COPY,G TAPEIN..L11.
14	@COPY,G TAPEIN..L12.
15	@COPY,G TAPEIN..L13.
16	@COPY,G TAPEIN..L14.
17	@COPY,G TAPEIN..L15.
18	@COPY,G TAPEIN..L16.
19	@COPY,G TAPEIN..L17.
20	@FREE TAPEIN.

@PRT,S XX.SOURCE

ORIGINAL PAGE 19
OF POOR QUALITY

APETITBING, 9*XX(1).SOURCE

7 3FTN,S XX.MAIN,XX.
1 3FTN,S XX.DATALD,XX.
3 3FTN,S XX.FEDAT,XX.
4 3FTN,S XX.FROCAL,XX.
5 3FTN,S XX.BNDAL,XX.
6 3FTN,S XX.MULCV,XX.
7 3FTN,S XX.VPNMC,XX.
8 3FTN,S XX.PRMAL,XX.
9 3FTN,S XX.MDLPRM,XX.
10 3FTN,S XX.CALC,XX.
11 3FTN,S XX.DFCALC,XX.
12 3FTN,S XX.HFREQ,XX.
13 3FTN,S XX.SEAPRM,XX.
14 3FTN,S XX.SEARES,XX.
15 3FTN,S XX.ALLOC,XX.
16 3FTN,S XX.DALLOC,XX.
17 3FTN,S XX.REVERB,XX.
18 3PACK XX.
19 3PREP TPFs
20 3MAP,S XX.NAM,XX.PP0
21 3XCT XX.PP0
22 3ACD,P XX.DATA

APRT,S XX.SOURCE2

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MPETITBYN303*XX(1).SOURC2

1 BXQT XX.PRO
2 @ADD.P XX.DATA

@PRT,S XX.NAM

MOETITBIN3C6*xy(1).NAM

```
1 LIB XX:
2 LIB SYSS*MSFCS
3 SEG MAINS
4     IN XX.MAIN
5     IN XX.ALLOC
6     IN XX.DALLOC
7     IN BLANKCOMMON
8     TYPE COMSEG
9 SEG A*
10    IN XX.DATALD
11    IN XX.FEDAT
12 SEG B*,A
13    IN XX.FRCAL
14 SEG C*,A
15    IN XX.BNDAL
16 SEG D*,A
17    IN XX.PRMAL
18 SEG E*,A
19    IN XX.MULCV
20 SEG F*,A
21    IN XX.VPNMC
22 SEG G*,A
23    IN XX.CALC
24 SEG H*,A
25    IN XX.DFCALC
26 SEG I*,A
27    IN XX.HFREQ
28 SEG J*,A
29    IN XX.MDLPRM
30    IN XX.SEAPRM
31    IN XX.SEARES
32    IN XX.REVERB
```

MOETITBIN36*XY(1).NAM

```
1 LIB XX.  
2 LIB SYS**MSFCE  
3 SEG MAINS  
4   IN XX.MAIN  
5   IN XX.ALLOC  
6   IN XX.DALLOC  
7   IN PLANKCOMMON  
8   TYPE COMSEG  
9 SEG A*  
10  IN XX.DATALD  
11  IN XX.FEDAT  
12 SEG B*,A  
13  IN XX.FRCAL  
14 SEG C*,A  
15  IN XX.BNDCAL  
16 SEG D*,A  
17  IN XX.PRCAL  
18 SEG E*,A  
19  IN XX.MULCV  
20 SEG F*,A  
21  IN XX.VPRMC  
22 SEG G*,A  
23  IN XX.CALC  
24 SEG H*,A  
25  IN XX.BFCALC  
26 SEG I*,A  
27  IN XX.HFREO  
28 SEG J*,A  
29  IN XX.MDLPRM  
30  IN XX.SEAPRM  
31  IN XX.SEARES  
32  IN XX.REVERB
```

ORIGINAL PAGE 19
OF POOR QUALITY

MPETITBIN306*XX(1).TAPOT

```
1  @ASG,TF TAPEOT.,T.SAVE04
2  @COPY,G L0.,TAPEOT.
3  @COPY,G L1.,TAPEOT.
4  @COPY,G L2.,TAPEOT.
5  @COPY,G L3.,TAPEOT.
6  @COPY,G L4.,TAPEOT.
7  @COPY,G L5.,TAPEOT.
8  @COPY,G L6.,TAPEOT.
9  @COPY,G L7.,TAPEOT.
10 @COPY,G L8.,TAPEOT.
11 @COPY,G L9.,TAPEOT.
12 @COPY,G L10.,TAPEOT.
13 @COPY,G L11.,TAPEOT.
14 @COPY,G L12.,TAPEOT.
15 @COPY,G L13.,TAPEOT.
16 @COPY,G L14.,TAPEOT.
17 @COPY,G L15.,TAPEOT.
18 @COPY,G L16.,TAPEOT.
19 @COPY,G L17.,TAPEOT.
20 @FREE TAPEOT.
```

@RRKPT PRINTS

MPETITBIN308*XX(1).DATA1

```

1  MULTIPLE CAVITY CHECK CASE
2  MARK PETITT
3  1  A.OPTION SELECTION
4  3
5  1,0,0,0
6  0,0,0,0
7  1,1,0,0
8  1  B.NEW DATA FILE SIZING PARAMETERS
9  3,5,4,20,2,5,4,5,60,20,0,0,60,4
10 1  C.RANGE: FREQUENCY DOMAIN
11 1,16,16,0.12
12 0  D.RANGE: DISCRETE FREQUENCIES
13 1  E.TOLERANCES
14 0.001,0.01
15 1  F.MATRIX SIZING
16 13,4,2,2,0,3,15,5,2,4,60,20,0,0,0,0,4
17 1  G.MULTIPLE CAVITY PARAMETERS
18 60,1,13,10,60,0,02,5,0,01
19 1  H.OPENING/VOLUME RELATIONSHIPS
20 1,1,2
21 1  I.OPENING DESCRIPTION
22 1,1,11,09,0,9,6
23 1  J.STRUCTURAL DATA FILE ACCESS AND STORAGE
24 0,0
25 1,2
26 1  K.GLOBAL NODE POINTS
27 1, 9.29,0.0,0.0
28 2, 9.29,0.0,5.04
29 3, 9.29,4.41,0.0
30 4, 0.0,4.41,0.0
31 5, 0.0,4.41,5.04
32 6, 4.645,4.41,0.0
33 7, 4.645,4.41,5.04
34 8, 4.645,2.2,0.0
35 9, 4.645,2.2,5.04
36 10, 0.0,0.0,0.0
37 11, 4.645,0.0,0.0
38 12, 0.0,0.0,5.04
39 13, 4.645,0.0,5.04
40 1  L.SURFACE DESCRIPTION
41 1, 1,22.23,1,2,3
42 2, 1,46.92,4,5,3
43 3, 1,23.41,4,5,6
44 4, 1,23.41,6,7,3
45 1  M.MASTER SURFACE / SURFACE RELATIONS
46 1, 0,0
47 2, 3,4
48 0  N.STRUCTURAL CONSTANTS
49 0  O.STRUCTURAL MODAL DATA
50 0  P.STRUCTURAL CONSTANTS : SEA
51 1  Q.VOLUME DESCRIPTION
52 1, 1,103.24,10,11,4,12
53 2, 1,103.24,11,1,6,13
54 1  R.ACOUSTIC CONSTANTS
55 4.428E-5,13200.0,3,GE-08
56 0  S.ACOUSTIC MODAL DATA

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57	1	T.SURFACE /VOLUME RELATIONSHIPS
58	1,2	
59	2,0	
60	3,1	
61	4,2	
62	0	U.SURFACE ABSORPTION
63	0	V.STRUCTURAL DAMPING
64	0	W.EXTERNAL SOUND PRESSURE LEVEL
65	0	X.EXTERNAL PRESSURE FIELD DESCRIPTION
66	1	Y.BAND CENTER FREQUENCIES
67		200.,250.,315.,400.,500.,630.,800.,
68		1000.,1250.,1600.,2000.,2500.,3150.,4000.,5000.,6300.,8000.,10000.,12500.,16000.
69	0	Z.REVERBERATION TIME

SPRT,S XX,DATA1A

```

MPEITBIN308#XX(1).DATA1A
1    MULTIPLE CAVITY CHECK CASE : 3 CAVITIES
2    MARK PETITT
3      1    A.OPTION SELECTION
4        E
5        0,0,0,1
6        0,0,0,0
7        0,1,0,0
8      1    B.NEW DATA FILE SIZING PARAMETERS
9        3,5,4,20,3,5,4,5,50,20,0,0,50,4
10     1    C.RANGE: FREQUENCY DOMAIN
11       1,16,16,0,12
12     0    D.RANGE: DISCRETE FREQUENCIES
13     1    E.TOLERANCES
14       0,001,0,01
15     1    F.MATRIX SIZING
16       14,4,2,2,0,3,15,5,3,4,50,20,0,0,0,0,4
17     1    G.MULTIPLE CAVITY PARAMETERS
18       50,2,10,10,49,0,02,10,0,01
19     1    H.OPENING/VOLUME RELATIONSHIPS
20       1,1,2
21       2,2,3
22     1    I.OPENING DESCRIPTION
23       1,1,20,89,3,12,11
24       2,1,11,09,7,13,14
25     1    J.STRUCTURAL DATA FILE ACCESS AND STORAGE
26       0,0
27       1,2
28     1    K.GLOBAL NODE POINTS
29       1,0,,0,,0,.
30       2,4,145,0,,0,.
31       3,0,,2,2,0,.
32       4,0,,0,,5,04
33       5,5,145,0,,0,.
34       6,9,29,0,,0,.
35       7,5,145,2,2,0,.
36       8,5,145,0,,5,04
37       9,9,29,2,2,0,.
38       10,0,,4,41,0,.
39       11,0,,2,2,5,04
40       12,4,145,2,2,0,.
41       13,5,145,2,2,5,04
42       14,5,145,4,41,0,.
43     1    L.SURFACE DESCRIPTION
44       1, 1,23,23,1,2,3
45       2, 1,46,92,4,5,3
46       3, 1,23,41,4,5,6
47       4, 1,23,41,6,7,3
48     1    M.MASTER SURFACE / SURFACE RELATIONS
49       1, 0,0
50       2, 3,4
51     0    N.STRUCTURAL CONSTANTS
52     0    O.STRUCTURAL MODAL DATA
53     0    P.STRUCTURAL CONSTANTS : SEA
54     1    Q.VOLUME DESCRIPTION
55       1,1,45,96,1,2,3,4
56       2,1,57,05,3,7,10,11

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57	3,1,91.92,5,6,14,8
58	1 R.ACOUSTIC CONSTANTS
59	4.428E-5,13200.0,3.0E-08
60	0 S.ACOUSTIC MODAL DATA
61	1 T.SURFACE /VOLUME RELATIONSHIPS
62	1,2
63	2,0
64	3,1
65	4,2
66	0 U.SURFACE ABSORPTION
67	0 V.STRUCTURAL DAMPING
68	0 W.EXTERNAL SOUND PRESSURE LEVEL
69	0 X.EXTERNAL PRESSURE FIELD DESCRIPTION
70	1 Y.BAND CENTER FREQUENCIES
71	200.,250.,315.,400.,500.,630.,800.,
72	1000.,1250.,1600.,2000.,2500.,3150.,4000.,5000.,6300.,8000.,10000.,12500.,16000.
73	0 Z.REVERBERATION TIME

@PRT,S XX,DATA2

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MPE11TBIN308=XX(1).DATA2

```
1 MARK PETIIIT
2 MODAL ANALYSIS TEST CASE
3 1 A.
4 1
5 1,3,1,1
6 1,0,1,1
7 1,1,3,0
8 1 B.
9 2,4,4,20,2,6,8,6,40,25,0,0,15,0
10 1 C.
11 1,15,15,0,12
12 0 D.
13 1 E.
14 0.001,0.02
15 1 F.
16 8,6,1,1,5,6,25,6,1,4,40,15,0,0,0,0,1
17 0 G.
18 0 H.
19 0 I.
20 1 J.
21 0
22 1
23 1 K.
24 1, 0, 0, 0, 0.
25 2, 15.35, 0, 0.
26 3, 15.35, 0, 12.21
27 4, 0, 0, 0, 0, 12.21
28 5, 0, 19.11, 0.
29 6, 15.35, 18.11, 0.
30 7, 15.35, 18.11, 12.21
31 8, 0, 0, 18.11, 12.21
32 1 L.
33 1, 8, 187.42, 5, 6, 8, 5, 6, 8
34 2, 8, 277.99, 1, 2, 5, 1, 2, 5
35 3, 8, 221.21, 2, 3, 6, 2, 3, 6
36 4, 8, 277.99, 4, 3, 8, 4, 3, 8
37 5, 8, 221.21, 1, 4, 5, 1, 4, 5
38 6, 8, 187.42, 1, 2, 4, 1, 2, 4
39 1 M.
40 1, 1
41 1 N.
42 1, 238., 238., 79., 0.33, 0.33, 1.6304E-5
43 0 O.
44 0 P.
45 1 Q.
46 1, 1, 3422.0, 1, 2, 5, 4
47 1 R.
48 .11468E-6, 13200., 3.0E-9
49 0 S.
50 1 T.
51 1, 1
52 2, 1
53 3, 1
54 4, 1
55 5, 1
56 6, 1
```


ORIGINAL PAGE 13
OF POOR QUALITY

57	1 U.
58	1,1
59	.005,.005,.005,.005,.005,.005,.005,.005,.005,.005,.005,.005,
60	.005,.005
61	2,0
62	3,0
63	4,0
64	5,0
65	6,0
66	1 V.
67	1,1
68	.01,.01,.01,.01,.01,.01,.01,.01,.01,.01,.01,.01,.01,.01,
69	1 W.
70	1,1
71	117.6,118.6,119.6,120.6,121.6,122.6,123.6,124.6,125.6,126.6,127.6,128.6,129.6,
72	130.6,131.6
73	1 X.
74	1,3
75	1.5708
76	1 Y.
77	40.,50.,63.,80.,100.,125.,160.,200.,250.,315.,400.,500.,630.,800.,1000.
78	0 Z.

APRT,S XX.DAT3

ORIGINAL PAGE IS
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MPEIITBIN308*YX(1).DATA

1	MARK PETTITT
2	SEA TEST CASE : OIL DRUM
3	1 A.
4	1
5	0,0,0,1
6	0,0,0,0
7	0,1,0,0
8	1 B.
9	2,4,4,20,2,5,5,15,15,0,0,15,4
10	1 C.
11	3,3,20,0.125
12	1 D.
13	1 E.
14	0.0001,0.02
15	1 F.
16	6,1,1,1,0,5,0,0,1,4,0,20,0,0,0,3,1
17	0 G.
18	0 H.
19	0 I.
20	1 J.
21	0,1,0
22	1,1,2
23	1 K.
24	1,0,0,0,0
25	2,11,0,0,0
26	3,0,11,0,0
27	4,0,0,0,33
28	5,11,0,0,33
29	6,0,11,0,33
30	1 L.
31	1,0,2200.8,0,0,0,0,0
32	1 M.
33	1,1
34	0 N.
35	0 O.
36	1 P.
37	1,2
38	1,11,0,0,0,0,0
39	2,33,0,0,0,0,0
40	3,0,04,0,0,0,0
41	4,6.706E-2,0,0,0,0
42	5,73042,0,0,0,0,0
43	6,202030,0,0,0
44	7,-1,0,0,0,0,0
45	1 Q.
46	1,2,12544,0,1,2,3,4
47	1 R.
48	.11468E-6,13200,0,3.0E-8
49	0 S.
50	1 T.
51	1,1
52	1 U.
53	1,1
54	.0067,.0067,.0084,.0105,.0132,.0167,.0209,.0264,.0335,.0419,.0523,.0670,
55	.0837,.1047,.1319,.1675,.2093,.2637,.3349,.4166
56	1 V.

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57	1,1
58	.01,.01,.01,.01,.01,.01,.01,.01,.01,.01,.01,.01,.01,.01,.01,.01
59	1 W.
60	1,1
61	100.,100.,100.,100.,100.,100.,100.,100.,100.,100.,100.,100.,100.,100.,100.,
62	100.,100.,100.,100.,100.,100.
63	1 X.
64	1,1
65	0.0
66	1 Y.
67	125.,160.,200.,250.,315.,400.,500.,630.,800.,1000.,1250.,1600.,2000.,2500.,
68	3150.,4000.,5000.,6300.,8000.,10000.
69	0 Z.

@PRT,S XX.DAT11

MPETITBIN308#X(1).DATA11

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ORIGINAL PAGE IS
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57	0 x.
58	1 y.
59	100.,125.,160.,200.,250.,315.,400.,500.,630.,800.,1000.,1250.,1600.,
60	2000.,2500.
61	0 z.

@PRT,S XX.DAT20

ORIGINAL PAGE IS
OF POOR QUALITY

MPE ITBIN308*XY(1).DATA20

1	MARK PETTIT
2	SPACE SHUTTLE EMPTY PAYLOAD BAY-OV101 JET TEST (LOW FREQ)
3	1 A.
4	1
5	0,0,0,0
6	0,0,0,0
7	0,1,0,0
8	1 B.
9	2,6,4,20,2,6,6,6,50,50,1,9,0,3
10	1 C.
11	1,8,3,0.125
12	0 D.
13	1 E.
14	0.001,0.01
15	1 F.
16	16,5,5,1,0,6,50,6,1,5,10,8,0,1,9,0,4
17	0 G.
18	0 H.
19	0 I.
20	1 J.
21	0,0,0,3,0
22	1,0,3,3,4
23	1 K.
24	1,582.0,-105.0,275.0
25	2,1302.0,-105.0,275.0
26	3,582.0,105.0,275.0
27	4,582.0,-105.0,419.0
28	5,1302.0,-105.0,419.0
29	6,582.0,105.0,419.0
30	7,1302.0,105.0,275.0
31	8,582.0,-105.0,474.0
32	9,582.0,0,275.0
33	10,1302.0,0,275.0
34	11,582.0,-105.0,327.0
35	12,1302.0,-105.0,327.0
36	13,582.0,105.0,327.0
37	14,1302.0,105.0,327.0
38	15,582.0,0,419.0
39	16,1302.0,0,419.0
40	1 L.
41	1,7,216880.,15,16,6,4,5,6
42	2,7,151200.,9,10,3,1,2,3
43	3,7,103680.,11,12,4,1,2,4
44	4,7,103680.,13,14,6,3,7,6
45	5,2,46977.,2,7,5,2,7,5
46	1 M.
47	1,1
48	2,2
49	3,3
50	4,4
51	5,5
52	1 N.
53	1,50.,127.,0.,0.,0.,0.
54	7.4,1.,1.,1.3,1.,540.,176.8,180.,62.6
55	8.9,2.,1.,1.1,.,99,550.,173.4,170.,65.3
56	10.1,3.,1.,1.2,.,61,660.,165.,50.,69.5

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57	10.4,3.,1.,10.4,1.,56,660.,159.6,50.,72.2
58	12.2,1.,2.,2.,1.,680.,241.,0.,31.2
59	13.2,1.,2.,2.4,1.,600.,241.7,70.,31.2
60	16.5,1.,2.,1.8,1.,520.,241.7,200.,31.2
61	17.1,2.,1.,1.4.,87,380.,146.,0.,79.
62	17.2,2.,1.,9.,76,350.,157.,0.,73.5
63	17.4,3.,1.,9.,59,495.,157.,0.,73.5
64	18.7,4.,1.,1.3.,8,660.,144.6,60.,79.7
65	19.7,3.,1.,9.,87,534.,137.,186.,83.1
66	20.7,2.,2.,1.4.,96,720.,241.7,0.,31.2
67	21.4,2.,2.,2.1.,94,560.,241.7,0.,31.2
68	22.4,5.,1.,8.,81,650.,146.,70.,79.
69	23.8,2.,2.,1.5.,76,620.,241.7,0.,31.2
70	24.5,1.,2.,2.2,1.,340.,241.7,370.,31.2
71	27.,6.,1.,1.2.,77,672.,137.8,48.,83.1
72	27.3,6.,1.,1.,87,660.,146.,60.,79.
73	27.8,3.,2.,1.1.,95,660.,241.7,0.,31.2
74	29.1,2.,2.,1.8.,89,370.,241.7,350.,31.2
75	33.4,7.,1.,2.,96,658.,151.4,62.,76.3
76	33.8,7.,1.,6.,71,658.,137.8,62.,83.1
77	34.7,3.,2.,2.3.,95,510.,241.7,0.,31.2
78	35.5,3.,2.,1.9.,88,495.,241.7,0.,31.2
79	37.4,4.,2.,1.4.,84,720.,241.7,0.,31.2
80	38.8,3.,3.,2.8.,94,480.,241.7,140.,31.2
81	40.3,5.,2.,1.6.,99,680.,241.7,0.,31.2
82	40.6,8.,1.,9.,88,658.0,144.6,32.0,79.7
83	43.5,5.,2.,1.9.,84,720.,241.7,0.,31.2
84	44.8,6.,2.,1.1.,75,700.,200.8,0.,51.6
85	46.4,5.,2.,2.1.,84,540.,200.8,0.,51.6
86	46.8,9.,1.,9.,81,655.,144.,50.,80.
87	47.1,4.,2.,1.2.,87,410.,228.,0.,38.
88	47.9,3.,2.,1.1.,79,330.,208.,275.,48.
89	48.8,7.,2.,2.4.,78,683.,228.,0.,38.
90	49.3,5.,2.,1.6.,76,500.,200.8,0.,51.6
91	49.7,5.,2.,1.5.,73,450.,200.8,0.,51.6
92	50.3,5.,2.,1.2.,93,430.,200.8,0.,51.6
93	51.0,8.,2.,1.2.,59,680.,200.8,0.,51.6
94	51.4,4.,2.,9.,71,400.,200.,240.,52.
95	52.2,1.,2.,1.,93,310.,200.8,225.0,51.6
96	53.2,4.,3.,2.4.,66,540.,228.,40.,36.
97	54.2,8.,4.,1.1.,53,620.,304.,0.,0.
98	54.2,6.,2.,1.2.,95,500.,200.8,200.,51.6
99	55.0,1.,4.,1.2.,87,295.,304.,55.,0.
100	55.,10.,3.,2.5.,83,700.,236.,25.,34.
101	55.5,5.,2.,1.4.,88,370.,200.8,205.0,51.6
102	55.8,10.,1.,9.,92,700.,173.4,25.,65.3
103	56.9,7.,1.,9.,79,500.,200.,115.,52.
104	2,45.,-1.0,0.,0.,0.,0.
105	9.6,1.,1.,5.4,1.,518.,210.,207.,0.
106	11.5,2.,1.,7.3.,9,609.,210.,116.,0.
107	18.3,1.,1.,7.5,1.,508.,210.,217.,0.
108	18.5,1.,1.,4.7,1.,458.,210.,267.,0.
109	19.5,2.,1.,4.1.,74,667.,210.,58.,0.
110	20.7,2.,1.,4.6.,93,667.,210.,58.,0.
111	22.9,2.,1.,4.7.,64,398.,201.,327.,4.5
112	23.1,2.,1.,23.1,5.4.,93,458.,204.,267.,3.
113	24.,3.,1.,3.5.,78,683.0,205.,116.,2.5

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114	25.4,2.,1.,9.,77,408.,210.,317.,0.
115	27.1,3.,1.,2.8.,67,483.,197.,242.,0.5
116	29.7,3.,1.,4.1.,87,498.,195.,227.,7.5
117	30.9,4.,1.,3.1.,74,609.,194.,116.,8.
118	33.,2.,1.,2.3,1.,171.,171.,167.,19.5
119	35.5,3.,1.,1.6.,81,428.,171.,297.,19.5
120	36.6,1.,1.,2.1.,85,334.,199.,166.,5.5
121	38.,2,4.,1.,1.3.,88,398.,168.,327.,21.
122	38.5,2.,1.,1.8.,84,254.,173.,388.,18.5
123	39.3,3.,1.,1.1.,72,283.,185.,217.,12.5
124	42.3,4.,1.,1.3.,69,255.,169.,20.5,417.
125	43.2,1.,1.,9,1.,141.,163.,444.,23.5
126	44.,2,2.,1.,9.,73,161.,189.,169.,10.5
127	45.5,2.,1.,2.1.,9,230.,165.,337.,22.5
128	46.4,1.,1.,1.1,1.,111.,172.,167.,19.
129	53.2,2.,1.,2.1.,98,357.,180.,0.,15.
130	55.4,1.,1.,1.5,1.,156.,153.,0.,28.5
131	56.6,2.,1.,2.3.,93,190.,163.,92.,21.
132	57.9,1.,1.,1.7,1.,227.,145.,472.0,32.5
133	62.6,1.,1.,1.8,1.,62.,210.,139.,0.
134	64.5,2.,1.,2.6,1.,160.,210.,47.,8.
135	71.9,1.,1.,1.6,1.,101.,180.,116.,15.
136	75.2,1.1,1.1,3.3,1.,101.,166.,116.,22.
137	75.9,1.,1.,1.4,1.,101.,174.,116.,10.
138	77.4,1.,3.,2.5.,85,211.,210.,177.,0.
139	78.5,1.,1.,1.5,1.,112.,130.,388.,40.
140	80.,3.,1.,1.3,-,31,279.,210.,116.,0.
141	80.7,3.,1.,1.5.,47,117.,210.,337.,0.
142	81.1,3.,1.,1.3.,35,300.,210.,116.,0.
143	81.8,3.,1.,1.9.,39,448.,210.,166.,0.
144	82.8,3.,1.,1.4.,43,211.,210.,166.,0.
145	84.2,3.,1.,1.,-45,102.,210.,507.,0.
146	85.1,3.,1.,2.,4,160.,210.,217.,0.
147	85.8,3.,1.,2.6.,39,204,210.,397.,0.
148	86.9,2.,1.,1.2.,81,166.,145.,0.,32.5
149	87.9,2.,1.,1.4.,38,166.,145.,0.,32.5
150	3,36.,-1.0,0.,0.,0.,0.
151	7.4,1.,1.,3.7,1.0,500.,104.,190.,0.
152	16.5,1.,1.,2.5,1.0,440.,108.,275.,0.
153	19.2,2.,1.,3.,99,650.,104.,75.,0.
154	21.4,2.,1.,3.3.,95,505.,100.,220.,0.
155	23.4,3.,1.,4.,94,570.,100.,75.,0.
156	23.8,3.,1.,2.4.,75,645.,102.,80.,0.
157	29.1,4.,1.,2.5.,9,680.,110.,45.,0.
158	38.6,5.,1.,3.2.,68,700.,74.,25.,0.
159	43.5,6.,1.,2.5.,76,660.,110.,65.,0.
160	44.2,6.,1.,3.1.,93,660.,90.,65.,20.
161	45.9,1.,2.,3.2,1.,265.,118.,460.,0.
162	46.4,2.,1.,2.,73,375.,80.,350.,40.
163	46.5,2.,1.,2.9,1.,215.,115.,510.,0.
164	47.1,3.,1.,2.4.,93,240.,85.,485.,30.
165	47.9,4.,1.,2.,22,360.,90.,290.,25.
166	48.8,5.,1.,1.5.,67,300.,78.,395.,30.
167	52.1,3.,1.,1.5.,61,216.,60.,375.,30.
168	53.1,3.,1.,2.4.,95,255.,75.,255.,30.
169	56.2,6.,1.,3.3.,63,546.,65.,20.,40.
170	59.5,4.,1.,2.9.,57,550.,70.,175.,30.

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171	61.4,3.,1.,2.5.,93,220.,80.,205.,20.
172	74.3,4.,1.,3.4.,74,400.,70.,325.,40.
173	74.6,7.,2.,2.4.,75,660.,105.,65.,0.
174	75.4,5.,1.,1.9.,66,400.,75.,0.,35.
175	76.8,3.,1.,2.3.,74,225.,120.,0.,0.
176	77.3,4.,1.,2.3.,73,320.,85.,0.,20.
177	78.9,1.,1.,2.1.,1.,120.,95.,50.,25.
178	79.7,1.,2.,2.,9,225.,100.,500.,0.
179	81.,3.,2.,3.1.,99,405.,111.,40.,0.
180	82.9,1.,2.,2.5,1.,225.,105.,425.,0.
181	83.4,4.,1.,2.7.,84,240.,80.,60.,35.
182	83.5,4.,1.,1.5.,75,230.,80.,60.,35.
183	84.8,3.,1.,4.,84,255.,75.,60.,25.
184	85.2,2.,1.,2.2.,79,150.,65.,165.,40.
185	87.9,3.,1.,2.2.,74,190.,73.,65.,32.
186	89.4,1.,1.,2.5,1.,125.,80.,25.,40.
187	4
188	5,120000.,446000.,2632.0,0.33,0.33,0.0212
189	0 0.
190	0 P.
191	1 3.
192	1,4,27851904.0,1,2,3,4,8
193	1 R.
194	.11468E-6,13200.,0.3E-8
195	0 3.
196	1 T.
197	1,1
198	2,1
199	3,1
200	4,1
201	5,1
202	1 U.
203	1,1
204	0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05
205	2,1
206	0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05
207	3,1
208	0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05
209	4,1
210	0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05
211	5,1
212	0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05
213	1 V.
214	1,1
215	0.032,0.025,0.02,0.016,0.0125,0.010,0.008,.00625
216	2,1
217	0.064,0.05,0.04,0.032,0.025,0.020,0.016,.0125
218	3,1
219	0.064,0.05,0.04,0.032,0.025,0.020,0.016,.0125
220	4,1
221	0.064,0.05,0.04,0.032,0.025,0.020,0.016,.0125
222	5,1
223	0.064,0.05,0.04,0.032,0.025,0.020,0.016,.0125
224	1 W-EXTERIOR SPL
225	1,1
226	98.,102.,105.,110.,112.,115.,115.,114.
227	2,1

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228	102.,108.,110.,112.,114.,118.,122.,125.
229	3,1
230	100.,102.,108.,110.,115.,118.,120.,122.
231	4,1
232	100.,102.,108.,110.,115.,118.,120.,122.
233	5,1
234	100.,102.,108.,110.,115.,118.,120.,122.
235	1 X.
236	1,2
237	0.0258,0.93,0.05,0.27
238	2,2
239	0.0258,0.93,0.05,0.27
240	3,2
241	0.0258,0.93,0.05,0.27
242	4,2
243	0.0258,0.93,0.05,0.27
244	5,1
245	1.,1.,1.,1.
246	1 Y.
247	31.5,40.,50.,63.,80.,100.,125.,160.
248	0 Z.

APRI,S XX.DAT21

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MPE IITBIN308*YX(1).DATA21

1	MARK PETTIT
2	SPACE SHUTTLE :EMPTY PAYLOAD 5AY,0V102 JET TEST(HIGH FREQ)
3	1 A.
4	1
5	0,1,0,0
6	0,0,0,0
7	0,1,0,0
8	1 B.
9	2,6,4,20,2,45,6,6,0,0,0,0,0,3
10	1 C.
11	3,3,20,0.125
12	0 D.
13	1 E.
14	0.001,0.01
15	1 F.
16	0,41,41,1,1,0,0,0,1,1,0,20,0,0,0,3,4
17	0 G.
18	0 H.
19	0 I.
20	1 J.
21	0,0,2,2,2,2,2,2,2,2,2,0,6,0,3,3,3,3,3,3,0,4,4,4,3,3,3,3,3,3,3,
22	4,4,4,4,1,0
23	1,2,2,2,2,2,2,2,2,2,2,6,6,3,3,3,3,3,3,3,4,4,4,4,3,3,3,3,3,3,3,
24	4,4,4,4,1,5
25	0 K.
26	1 L.
27	1,0,109440.,0
28	2,0,11634.,0
29	3,0,11634.,0
30	4,0,11634.,0
31	5,0,11634.,0
32	6,0,11634.,0
33	7,0,11634.,0
34	8,0,11634.,0
35	9,0,11634.,0
36	10,0,11634.,0
37	11,0,11634.,0
38	12,0,11634.,0
39	13,0,12180.,0
40	14,0,12180.,0
41	15,0,4927.8,0
42	16,0,4927.8,0
43	17,0,4927.8,0
44	18,0,4927.8,0
45	19,0,4927.8,0
46	20,0,4927.8,0
47	21,0,4927.8,0
48	22,0,4927.8,0
49	23,0,5073.0,0
50	24,0,5073.0,0
51	25,0,5073.0,0
52	26,0,5073.0,0
53	27,0,5073.0,0
54	28,0,4927.8,0
55	29,0,4927.8,0
56	30,0,4927.8,0

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57	31,0,4927.8,0
58	32,0,4927.8,0
59	33,0,4927.8,0
60	34,0,4927.8,0
61	35,0,4927.8,0
62	36,0,5073.0,0
63	37,0,5073.0,0
64	38,0,5073.0,0
65	39,0,5073.0,0
66	40,0,109440.0,0
67	41,0,46977.0,0
68	1 M.
69	1,1
70	2,2
71	3,3
72	4,4
73	5,5
74	6,6
75	7,7
76	8,8
77	9,9
78	10,10
79	11,11
80	12,12
81	13,13
82	14,14
83	15,15
84	16,16
85	17,17
86	18,18
87	19,19
88	20,20
89	21,21
90	22,22
91	23,23
92	24,24
93	25,25
94	26,26
95	27,27
96	28,28
97	29,29
98	30,30
99	31,31
100	32,32
101	33,33
102	34,34
103	35,35
104	36,36
105	37,37
106	38,38
107	39,39
108	40,40
109	41,41
110	0 N.
111	0 0.
112	1 P.SEA CONSTANTS
113	1,3

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114	1,	1.19E-5,	1.6E-5,	.02
115	2,	4.46E-6,	5.44E-6,	.06
116	3,	6.70E-6,	4.12E-6,	.10
117	4,	1.49E-6,	5.96E-7,	.07
118	5,	1.78E-6,	3.96E-7,	.07
119	6,	7.43E-6,	9.96E-7,	.10
120	7,	1.19E-6,	1.28E-6,	.18
121	8,	2.20E-6,	6.20E-7,	.25
122	9,	1.04E-6,	7.88E-7,	.30
123	10,	6.68E-7,	5.04E-7,	.30
124	11,	5.20E-7,	4.48E-7,	.25
125	12,	4.83E-7,	2.78E-7,	.25
126	13,	4.46E-7,	2.51E-7,	.25
127	14,	4.46E-7,	1.78E-7,	.25
128	15,	4.16E-7,	1.24E-7,	.25
129	16,	3.27E-7,	7.92E-8,	.40
130	17,	2.53E-7,	4.00E-8,	.40
131	18,	1.78E-7,	3.09E-8,	.40
132	19,	1.19E-7,	1.98E-8,	.40
133	20,	7.43E-8,	1.27E-8,	.40
134	2,3			
135	1,	0.,0.,0.		
136	2,	0.,0.,0.		
137	3,	0.,0.,0.		
138	4,	3.57E-6,	9.E-6,	0.10
139	5,	3.57E-6,	9.E-6,	0.45
140	6,	3.57E-6,	9.6E-6,	0.45
141	7,	3.06E-6,	7.78E-6,	0.45
142	8,	5.10E-6,	9.5E-6,	0.45
143	9,	1.12E-5,	1.91E-5,	0.45
144	10,	9.18E-6,	1.55E-5,	0.45
145	11,	1.02E-6,	1.26E-5,	0.45
146	12,	2.04E-7,	9.54E-6,	0.45
147	13,	1.02E-7,	7.68E-6,	0.45
148	14,	6.12E-8,	6.12E-6,	0.45
149	15,	2.04E-8,	4.75E-6,	0.45
150	16,	1.02E-8,	3.83E-6,	0.45
151	17,	6.12E-9,	2.45E-6,	0.45
152	18,	2.04E-9,	1.5E-6,	0.45
153	19,	1.02E-9,	1.21E-6,	0.45
154	20,	6.12E-10,	9.73E-7,	0.45
155	3,3			
156	4,3			
157	5,3			
158	6,3			
159	7,3			
160	8,3			
161	9,3			
162	10,3			
163	11,3			
164	12,3			
165	13,3			
166	1,	7.E-5,	7.11E-5,	0.1
167	2,	7.E-5,	5.5E-5,	0.12
168	3,	7.E-5,	5.3E-5,	0.08
169	4,	1.16E-5,	5.56E-5,	.06
170	5,	2.33E-5,	2.76E-5,	0.045

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171	6, 1.16E-5, 1.76E-5, 0.05
172	7, 1.32E-5, 1.41E-5, 0.045
173	8, 7.75E-6, 6.62E-6, 0.04
174	9, 4.65E-6, 6.95E-6, 0.045
175	10, 3.1E-6, 5.01E-6, .05
176	11, 3.26E-6, 4.45E-6, .05
177	12, 3.1E-6, 8.7E-6, 0.05
178	13, 3.1E-6, 9.9E-6, 0.05
179	14, 3.49E-6, 7.01E-6, 0.05
180	15, 6.98E-6, 6.89E-6, 0.05
181	16, 8.53E-6, 5.55E-6, 0.05
182	17, 5.43E-6, 4.46E-6, 0.05
183	18, 7.75E-7, 2.72E-6, 0.05
184	19, 1.55E-7, 1.74E-6, 0.05
185	20, 5.43E-8, 1.11E-6, 0.05
186	14, 3
187	15, 3
188	1, 0., 0., 0.
189	2, 0., 0., 0.
190	3, 0., 0., 0.
191	4, 0., 0., 0.
192	5, 0., 0., 0.
193	6, 0., 0., 0.
194	7, 0., 0., 0.
195	8, 0., 0., 0.
196	9, 1.43E-5, 5.66E-4, 0.07
197	10, 7.16E-6, 2.58E-4, 0.07
198	11, 3.58E-6, 2.03E-4, 0.09
199	12, 2.51E-6, 1.259E-4, 0.06
200	13, 1.43E-6, 3.06E-5, 0.09
201	14, 7.16E-7, 6.34E-5, 0.09
202	15, 3.58E-7, 4.42E-5, 0.09
203	16, 2.86E-7, 3.18E-5, .1
204	17, 1.79E-7, 2.28E-5, .1
205	18, 6.44E-8, 1.39E-5, .1
206	19, 3.22E-8, 1.0E-5, .1
207	20, 1.79E-8, 8.06E-6, 0.1
208	16, 3
209	17, 3
210	18, 3
211	19, 3
212	20, 3
213	21, 3
214	22, 3
215	23, 3
216	1, 0., 0., 0.
217	2, 0., 0., 0.
218	3, 0., 0., 0.
219	4, 0., 0., 0.
220	5, 0., 0., 0.
221	6, 0., 0., 0.
222	7, 0., 0., 0.
223	8, 0., 0., 0.
224	9, 1.49E-5, 6.35E-4, 0.03
225	10, 7.44E-6, 4.56E-4, 0.03
226	11, 3.72E-6, 3.23E-4, 0.03
227	12, 2.6E-6, 2.25E-4, 0.035

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228	13, 1.49E-6, 1.61E-4, 0.035
229	14, 7.44E-7, 1.14E-4, 0.04
230	15, 3.72E-7, 7.07E-5, 0.04
231	16, 2.86E-7, 5.08E-5, 0.045
232	17, 1.79E-7, 3.64E-5, 0.045
233	18, 6.44E-8, 2.50E-5, 0.045
234	19, 3.22E-8, 2.03E-5, 0.045
235	20, 1.79E-8, 1.15E-5, 0.045
236	24, 3
237	25, 3
238	26, 3
239	27, 3
240	28, 3
241	29, 3
242	30, 3
243	31, 3
244	32, 3
245	33, 3
246	34, 3
247	35, 3
248	36, 3
249	37, 3
250	38, 3
251	39, 3
252	40, 3
253	41, 1
254	1, 446000., 0., 0.
255	2, 120000., 0., 0.
256	3, 2632.0, 0., 0.
257	4, 0.33, 0., 0.
258	5, 0.33, 0., 0.
259	6, 0.0212, 0., 0.
260	7, 223.7, 0., 0.
261	8, 210., 0., 0.
262	9, -1., 0., 0.
263	0 0.
264	1 R.
265	.11468E-6, 13200., .3E-8
266	0 S.
267	1 T.
268	1, 1
269	2, 1
270	3, 1
271	4, 1
272	5, 1
273	6, 1
274	7, 1
275	8, 1
276	9, 1
277	10, 1
278	11, 1
279	12, 1
280	13, 1
281	14, 1
282	15, 1
283	16, 1
284	17, 1

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OF POOR QUALITY

285	18,1
286	19,1
287	20,1
288	21,1
289	22,1
290	23,1
291	24,1
292	25,1
293	26,1
294	27,1
295	28,1
296	29,1
297	30,1
298	31,1
299	32,1
300	33,1
301	34,1
302	35,1
303	36,1
304	37,1
305	38,1
306	39,1
307	40,1
308	41,1
309	1 U.
310	1,1
311	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
312	2,1
313	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
314	3,1
315	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
316	4,1
317	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
318	5,1
319	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
320	6,1
321	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
322	7,1
323	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
324	8,1
325	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
326	9,1
327	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
328	10,1
329	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
330	11,1
331	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
332	12,1
333	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
334	13,1
335	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
336	14,1
337	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
338	15,1
339	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
340	16,1
341	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14

ORIGINAL PAGE 19
OF POOR QUALITY

342	17,1
343	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
344	18,1
345	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
346	19,1
347	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
348	20,1
349	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
350	21,1
351	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
352	22,1
353	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
354	23,1
355	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
356	24,1
357	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
358	25,1
359	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
360	26,1
361	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
362	27,1
363	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
364	28,1
365	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
366	29,1
367	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
368	30,1
369	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
370	31,1
371	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
372	32,1
373	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
374	33,1
375	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
376	34,1
377	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
378	35,1
379	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
380	36,1
381	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
382	37,1
383	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
384	38,1
385	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
386	39,1
387	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
388	40,1
389	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
390	41,1
391	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
392	1 v.
393	1,1
394	.032,.025,.03,.016,.0125,.01,.008,.0063,.005,.004,.0032,.0025,.002,.0016,
395	.0013,.001,.0008,.00063,.00050,.0004
396	2,1
397	.064,.05,.06,.032,.025,.02,.016,.0126,.01,.008,.0064,.005,.004,.0032,
398	.0026,.002,.0016,.00126,.001,.0008

ORIGINAL PAGE IS
OF POOR QUALITY

LINE	DESCRIPTION	AMOUNT
395		3.0
400		4.0
401		5.0
402		6.0
403		7.0
404		8.0
405		9.0
406		10.0
407		11.0
408		12.0
409		13.1
410		14.0
411		15.1
412		16.0
413		17.0
414		18.0
415		19.0
416		20.0
417		21.0
418		22.0
419		23.1
420		24.0
421		25.0
422		26.0
423		27.0
424		28.0
425		29.0
426		30.0
427		31.0
428		32.0
429		33.0
430		34.0
431		35.0
432		36.0
433		37.0
434		38.0
435		39.0
436		40.0
437		41.1
438		42.0
439		43.0
440		44.0
441		45.0
442		46.0
443		47.0
444		48.0
445		49.0
446		50.0
447		51.0
448		52.0
449		53.0
450		54.0
451		55.0
452		56.0
453		57.0
454		58.0
455		59.0

ORIGINAL PAGE 12
OF POOR QUALITY

456	6,0
457	7,0
458	8,0
459	9,0
460	10,0
461	11,0
462	12,0
463	13,1
464	110.,111.,115.,116.,111.,124.,128.,128.,125.,125.,123.,120.,123.,120.,120.,119.,
465	117.,114.,113.,111.
466	14,0
467	15,1
468	108.,111.,115.,120.,122.,124.,123.,122.,121.,120.,118.,122.,124.,124.,124.,121.,
469	116.,113.,112.,114.
470	16,0
471	17,0
472	18,0
473	19,0
474	20,0
475	21,0
476	22,0
477	23,1
478	108.,111.,115.,120.,123.,124.,124.,122.,124.,124.,121.,126.,126.,125.,124.,121.,
479	121.,120.,117.,116.
480	24,0
481	25,0
482	26,0
483	27,0
484	28,1
485	108.,111.,115.,120.,122.,124.,123.,122.,121.,120.,118.,122.,124.,124.,124.,121.,
486	116.,113.,112.,114.
487	29,0
488	30,0
489	31,0
490	32,0
491	33,0
492	34,0
493	35,0
494	36,1
495	108.,111.,115.,120.,123.,124.,124.,122.,124.,124.,121.,126.,126.,125.,124.,121.,
496	121.,120.,117.,116.
497	37,0
498	38,0
499	39,0
500	40,0
501	41,1
502	102.,105.,110.,113.,118.,120.,122.,121.,120.,118.,118.,121.,120.,118.,
503	118.,117.,113.,112.,110.,108.
504	1 x.
505	1,2
506	.0258,.93,.05,.27
507	2,2
508	.0258,.93,.05,.27
509	3,0
510	4,0
511	5,0
512	6,0

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OF POOR QUALITY

513	7,0
514	8,0
515	9,0
516	10,0
517	11,0
518	12,0
519	13,2
520	.0258,.93,.05,.27
521	14,0
522	15,2
523	.0258,.93,.05,.27
524	16,0
525	17,0
526	18,0
527	19,0
528	20,0
529	21,0
530	22,0
531	23,2
532	.0258,.93,.05,.27
533	24,0
534	25,0
535	26,0
536	27,0
537	28,0
538	29,0
539	30,0
540	31,0
541	32,0
542	33,0
543	34,0
544	35,0
545	36,0
546	37,0
547	38,0
548	39,0
549	40,0
550	41,1
551	1.0,1.0,1.0,1.0
552	1 Y.
553	31.5,40.,50.,63.,80.,100.,125.,160.,200.,250.,315.,400.,500.,630.,800.,
554	1000.,1250.,1600.,2000.,2500.
555	0 2.

APRI,S XX.DATASC

ORIGINAL PAGE IS
OF POOR QUALITY

MPETITBIN306*XX(1).DATA30

1	MARK PETTITT
2	SIMPLE SPACE SHUTTLE WITH SPACELAB-2 PAYLOAD
3	1 A.
4	1
5	1,0,1,1
6	0,0,0,0
7	0,1,0,0
8	1 B.
9	3,5,4,20,3,10,4,6,50,50,1,9,50,3
10	1 C.
11	1,3,20,0.115J
12	0 0.
13	1 E.
14	0.001,0.02
15	1 F.
16	23,9,3,3,3,6,50,2,3,4,50,20,0,1,9,3,4
17	1 G.
18	50,2,5,1,10,.030,5,0.01
19	1 H.
20	1,1,2
21	2,2,3
22	1 I.
23	1,3,6786.0,5,6,20,0,0,0
24	2,3,23926.0,9,10,8,0,0,0
25	1 J.
26	0,0,2
27	1,2,2
28	1 K.
29	1, 0., 0., 0.
30	2, 0., 105., 0.
31	3, 0., 0., 105.
32	4, 200., 0., 25.
33	5, 200., 0., 0.
34	6, 200., 105., 0.
35	7, 200., 0., 105.
36	8, 320., 0., 84.
37	9, 320., 0., 0.
38	10, 320., 105., 0.
39	11, 320., 0., 105.
40	12, 720., 0., 40.
41	13, 0., -105., 0.
42	14, 200., -105., 0.
43	15, 320., -105., 0.
44	16, 720., 105., 0.
45	17, 720., -105., 0.
46	18, 720., 0., 0.
47	19, 0., 0., 25.
48	20, 200., 0., 84.
49	21, 0., 102., 25.
50	22, 200., 102., 25.
51	23, 200., -102., 25.
52	24, 320., 102., 25.
53	25, 320., 0., 25.
54	26, 320., -102., 25.
55	27, 720., 0., 25.
56	28, 720., -102., 25.

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57	29,5,.-102,25.
58	1 L.
59	1,7,218380.,19,27,21,29,28,21
60	2,0,109440.,0,0,0,0,0,0
61	3,0,109440.,0,0,0,0,0,0
62	4,7,60800.,19,27,21,29,23,21
63	5,7,36480.,19,27,21,23,26,22
64	6,7,121600.,19,27,21,26,28,24
65	7,6,66000.,1,5,13,13,6,6
66	8,6,39600.,5,9,14,14,10,10
67	9,6,132000.,9,18,15,15,16,16
68	1 M.
69	1,4,5,6
70	2,4,5,6
71	3,4,5,6
72	1 N.
73	1,50,96.
74	7,4,1,1,1,3,1,540.,178.8,180.,62.6
75	8,9,2,1,1,1,99,550.,173.4,170.,65.3
76	10,1,3,1,1,1,2,61,660.,165.,50.,69.5
77	10,4,3,1,1,10,4,1,56,660.,159.6,50.,72.2
78	12,2,1,2,2,2,1,680.,241.,0.,31.2
79	13,2,1,2,2,2,4,1,600.,241.7,70.,31.2
80	16,5,1,2,2,1,9,1,520.,241.7,200.,31.2
81	17,1,2,1,1,1,4,87,380.,146.,0.,79.
82	17,2,2,1,1,9,76,350.,157.,0.,73.5
83	17,4,3,1,1,9,59,495.,157.,0.,73.5
84	18,7,4,1,1,1,3,8,660.,144.6,60.,79.7
85	19,7,3,1,1,9,87,534.,137.,186.,83.1
86	20,7,2,2,1,4,96,720.,241.7,0.,31.2
87	21,4,2,2,2,1,94,560.,241.7,0.,31.2
88	22,4,5,1,1,8,61,650.,146.,70.,79.
89	23,8,2,2,1,5,76,620.,241.7,0.,31.2
90	24,5,1,2,2,2,1,340.,241.7,370.,31.2
91	27,6,1,1,1,2,77,672.,137.8,48.,83.1
92	27,3,6,1,1,1,87,660.,146.,60.,79.
93	27,8,3,2,1,1,95,660.,241.7,0.,31.2
94	29,1,2,2,1,8,86,370.,241.7,350.,31.2
95	33,4,7,1,1,2,96,658.,151.4,62.,76.3
96	33,8,7,1,1,6,71,658.,137.8,62.,83.1
97	34,7,3,2,2,3,95,510.,241.7,0.,31.2
98	35,5,3,2,1,8,88,495.,241.7,0.,31.2
99	37,4,4,2,1,4,84,720.,241.7,0.,31.2
100	38,8,3,3,2,8,94,480.,241.7,140.,31.2
101	40,3,5,2,1,6,99,680.,241.7,0.,31.2
102	40,6,8,1,1,9,86,658.0,144.6,32.0,79.7
103	43,5,5,2,1,9,84,720.,241.7,0.,31.2
104	44,8,6,2,1,1,75,700.,200.8,0.,51.6
105	46,4,5,2,2,1,84,540.,200.8,0.,51.6
106	46,8,9,1,1,9,81,655.,144.,50.,80.
107	47,1,4,2,1,2,87,410.,228.,0.,38.
108	47,9,3,2,1,1,79,330.,208.,275.,48.
109	48,8,7,2,2,4,78,663.,228.,0.,38.
110	49,3,5,2,1,6,76,500.,200.8,0.,51.6
111	49,7,5,2,1,5,73,450.,200.8,0.,51.6
112	50,3,5,2,1,2,93,430.,200.8,0.,51.6
113	51,0,8,2,1,2,59,680.,200.8,0.,51.6

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114	51.4,4.,2.,9.,71,400.,200.,240.,54.
115	52.2,1.,2.,1.,93,310.,200.8,225.0,51.6
116	53.2,4.,3.,2.4.,66,540.,228.,40.,38.
117	54.2,8.,4.,1.1.,53,620.,304.,0.,0.
118	54.2,6.,2.,1.2.,95,500.,200.8,200.,51.6
119	55.0,1.,4.,1.2.,87,295.,304.,55.,0.
120	55.,10.,3.,2.5.,83,700.,236.,25.,34.
121	55.5,5.,2.,1.4.,88,370.,200.8,205.0,51.6
122	55.8,10.,1.,9.,92,700.,173.4,25.,65.3
123	56.9,7.,1.,9.,79,500.,250.,115.,52.
124	2,0.,0.
125	3
126	0 0.
127	1 P. SEA CONSTANTS
128	1,0
129	2,3
130	1, 1.19E-5, 1.6E-5, .02
131	2, 4.46E-6, 5.44E-6, .06
132	3, 6.70E-6, 4.12E-6, .10
133	4, 1.49E-6, 5.96E-7, .07
134	5, 1.78E-6, 3.96E-7, .07
135	6, 7.43E-6, 9.96E-7, .10
136	7, 1.19E-6, 1.28E-6, .18
137	8, 2.20E-6, 6.20E-7, .25
138	9, 1.04E-6, 7.88E-7, .30
139	10, 6.68E-7, 5.04E-7, .30
140	11, 5.20E-7, 4.48E-7, .25
141	12, 4.83E-7, 2.78E-7, .25
142	13, 4.46E-7, 2.51E-7, .25
143	14, 4.46E-7, 1.78E-7, .25
144	15, 4.16E-7, 1.24E-7, .25
145	16, 3.27E-7, 7.92E-8, .40
146	17, 2.53E-7, 4.00E-8, .40
147	18, 1.78E-7, 3.09E-8, .40
148	19, 1.19E-7, 1.98E-8, .40
149	20, 7.43E-8, 1.27E-8, .40
150	3,3
151	1 J.
152	1,3,5397884.5,1,2,3,4
153	2,3,814301.,5,6,7,8
154	3,3,3046400.,9,10,11,12
155	1 R.
156	.11468E-6,13200.,.3E-8
157	0 S.
158	1 T.
159	1,0
160	2,0
161	3,0
162	4,1
163	5,2
164	6,3
165	7,1
166	8,2
167	9,3
168	1 U.
169	1,1
170	.01.,.0096.,.0073.,.0056.,.0081.,.0063.,.0098.,.0046.,.0034.,.0034.,.0033.,.0023.,.0018.,

ORIGINAL PAGE IS
OF POOR QUALITY

171	.0010,.0006,.00065,.00053,.00044,.00037
172	2,1
173	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
174	3,1
175	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
176	4,1
177	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
178	5,1
179	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
180	6,1
181	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
182	7,1
183	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
184	8,1
185	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
186	9,1
187	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
188	1 V.
189	1,1
190	.032,.025,.03,.016,.0125,.01,.008,.0063,.005,.004,.0032,.0025,.002,.0016,
191	.0013,.001,.0008,.00063,.00050,.0004
192	2,1
193	.064,.05,.06,.032,.025,.02,.016,.0125,.01,.008,.0064,.005,.004,.0032,
194	.0026,.002,.0016,.00125,.001,.0008
195	3,0
196	1,1
197	1,1
198	105,.109,.113,.115,.119,.121,.119,.115,.114,.117,.122,.126,.124,.120,.121,.120.,
199	117,.114,.115,.115.
200	2,1
201	105,.109,.113,.115,.119,.121,.119,.115,.114,.117,.122,.126,.124,.120,.121,.120.,
202	117,.114,.115,.115.
203	3,1
204	105,.109,.113,.115,.119,.121,.119,.115,.114,.117,.122,.126,.124,.120,.121,.120.,
205	117,.114,.115,.115.
206	1 X.
207	1,2
208	.0258,.93,.05,.27
209	2,2
210	.0258,.93,.05,.27
211	3,0
212	1 Y.
213	31.5,40,.50,.63,.80,.100,.125,.160,.200,.250,.315,.400,.500,.630,.800.,
214	1000,.1250,.1600,.2000,.2500.
215	0 C.

QPR1,S XX.DAT31

ORIGINAL PAGE IS
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MPE TITBIN308*XX(1).DATA31

1	MARK PETITT
2	SPACE SHUTTLE - EMPTY PAYLOAD BAY (CYLINDER MODEL:DOOR INPUT ONLY)
3	1 A.
4	1
5	0,0,1,1
6	0,0,0,0
7	0,1,0,0
8	1 B.
9	3,5,4,20,3,10,4,6,50,50,1,9,50,3
10	1 C.
11	1,4,4,0,1150
12	0 D.
13	1 E.
14	.001,.02
15	1 F.
16	29,5,4,1,1,6,50,2,1,4,50,20,0,1,9,3,4
17	0 G.
18	0 H.
19	0 I.
20	1 J.
21	0,0,2,0
22	1,2,2,3
23	1 K.
24	1, 0., 0., 0.
25	2, 0., 105., 0.
26	3, 0., 0., 105.
27	4,200.,0.,25.
28	5,200.,0.,0.
29	6,200.,105.,0.
30	7,200.,0.,105.
31	8,320.,0.,84.
32	9,320.,0.,0.
33	10,320.,105.,0.
34	11,320.,0.,105.
35	12,720.,0.,40.
36	13,0.,-105.,0.
37	14,200.,-105.,0.
38	15,320.,-105.,0.
39	16,720.,105.,0.
40	17,720.,-105.,0.
41	18,720.,0.,0.
42	19,0.,0.,25.
43	20,200.,0.,84.
44	21,0.,102.,25.
45	22,200.,102.,25.
46	23,200.,-102.,25.
47	24,320.,102.,25.
48	25,320.,0.,25.
49	26,320.,-102.,25.
50	27,720.,0.,25.
51	28,720.,-102.,25.
52	29,0.,-102.,25.
53	1 L.
54	1,7,2188dC.,19,27,21,29,28,21
55	2,0,109440.,0,0,0,0,0,0
56	3,0,109440.,0,0,0,0,0,0

ORIGINAL PAGE IS
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57	4.0,11634..0,0,0,0,0,0
58	5,6,237504..1,18,13,13,16,16
59	1 N.
60	1,1
61	2,2
62	3,3
63	4,4
64	1 N.
65	1.50.,96.
66	7.4,1.,1.,1.3,1.,540.,178.8,180.,62.6
67	8.9,2.,1.,1.1,.,99,550.,173.4,170.,65.3
68	10.1,3.,1.,1.2,.,61,660.,165.,50.,64.5
69	10.4,3.,1.,10.4,1.,56,660.,159.6,50.,72.2
70	12.2,1.,2.,2.,1.,680.,241.,0.,31.2
71	13.2,1.,2.,2.4,1.,600.,241.7,70.,31.2
72	16.5,1.,2.,1.8,1.,520.,241.7,200.,31.2
73	17.1,2.,1.,1.4,.,87,360.,146.,0.,79.
74	17.2,2.,1.,9.,76,350.,157.,0.,73.5
75	17.4,3.,1.,9.,59,495.,157.,0.,73.5
76	18.7,4.,1.,1.3,.,8,660.,144.6,60.,79.7
77	19.7,3.,1.,9.,87,534.,137.,186.,83.1
78	20.7,2.,2.,1.4,.,96,720.,241.7,0.,31.2
79	21.4,2.,2.,2.1,.,94,560.,241.7,0.,31.2
80	22.4,5.,1.,8.,81,650.,146.,70.,79.
81	23.8,2.,2.,1.5,.,76,620.,241.7,0.,31.2
82	24.5,1.,2.,2.2,1.,340.,241.7,370.,31.2
83	27.6,6.,1.,1.2,.,77,672.,137.8,48.,83.1
84	27.3,6.,1.,1.,87,660.,146.,60.,79.
85	27.8,3.,2.,1.1,.,95,660.,241.7,0.,31.2
86	29.1,2.,2.,1.8,.,69,370.,241.7,350.,31.2
87	33.4,7.,1.,2.,96,658.,151.4,62.,76.3
88	33.8,7.,1.,0.,71,658.,137.8,62.,83.1
89	34.7,3.,2.,2.3,.,95,510.,241.7,0.,31.2
90	35.5,3.,2.,1.8,.,88,495.,241.7,0.,31.2
91	37.4,4.,2.,1.4,.,84,720.,241.7,0.,31.2
92	38.8,3.,3.,2.8,.,94,480.,241.7,140.,31.2
93	40.3,5.,2.,1.6,.,99,680.,241.7,0.,31.2
94	40.6,8.,1.,9.,88,658.0,144.6,32.0,79.7
95	43.5,5.,2.,1.9,.,84,720.,241.7,0.,31.2
96	44.8,6.,2.,1.1,.,75,700.,200.8,0.,51.6
97	46.4,5.,2.,2.1,.,64,540.,200.8,0.,51.6
98	46.8,9.,1.,9.,81,655.,144.,50.,80.
99	47.1,4.,2.,1.2,.,87,410.,228.,0.,38.
100	47.9,3.,2.,1.1,.,79,330.,208.,275.,48.
101	48.8,7.,2.,2.4,.,78,683.,228.,0.,38.
102	49.3,5.,2.,1.6,.,76,500.,200.8,0.,51.6
103	49.7,5.,2.,1.5,.,73,450.,200.8,0.,51.6
104	50.3,5.,2.,1.2,.,93,430.,200.8,0.,51.6
105	51.0,8.,2.,1.2,.,59,680.,200.8,0.,51.6
106	51.4,4.,2.,9.,71,400.,200.,240.,52.
107	52.2,1.,2.,1.,93,310.,200.8,225.0,51.6
108	53.2,4.,3.,2.4,.,66,540.,228.,40.,36.
109	54.2,8.,4.,1.1,.,53,620.,304.,0.,0.
110	54.2,6.,2.,1.2,.,95,500.,200.8,200.,51.6
111	55.0,1.,4.,1.2,.,87,295.,304.,55.,0.
112	55.,10.,3.,2.5,.,83,700.,236.,25.,34.
113	55.5,5.,2.,1.4,.,88,370.,200.8,205.0,51.6

ORIGINAL PAGE IS
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114	55.8,10.,1.,.,9.,92,700.,173.4,25.,65.3
115	56.9,7.,1.,.,7.,79,500.,200.,115.,52.
116	2.0.,0.
117	3
118	4.0.,0.
119	0 0.
120	1 P. SEA CONSTANTS
121	1,0
122	2,3
123	1, .136E-2, .136E-2, .02
124	2, .105E-2, .105E-2, .06
125	3, .705E-3, .705E-3, .10
126	4, .152E-2, .152E-2, .07
127	5, .657E-3, .657E-3, .07
128	6, .485E-3, .485E-3, .10
129	7, .355E-3, .355E-3, .18
130	8, .377E-3, .377E-3, .25
131	9, .325E-3, .325E-3, .30
132	10, .232E-3, .232E-3, .30
133	11, .129E-3, .129E-3, .25
134	12, .819E-4, .819E-4, .25
135	13, .615E-4, .615E-4, .25
136	14, .711E-4, .711E-4, .25
137	15, .359E-4, .359E-4, .25
138	16, .254E-4, .254E-4, .40
139	17, .255E-4, .255E-4, .40
140	18, .178E-4, .178E-4, .40
141	19, .122E-4, .122E-4, .4
142	20, .633E-5, .633E-5, .40
143	3,3
144	4,1
145	1,1030350.,0.,0.
146	2,947.,0.,0.
147	3,1208.,0.,0.
148	4.,3.,0.,0.
149	5.,3.,0.,0.
150	6.,0.0336.,0.,0.
151	7,55.4.,0.,0.
152	8,210.,0.,0.
153	9,-1.0.,0.,0.
154	1 0.
155	1,2,24937920.,1,2,3,19
156	1 R.
157	.11468E-6,13200.,.3E-8
158	0 S.
159	1 T.
160	1,1
161	2,1
162	3,1
163	4,1
164	5,1
165	1 U.
166	1,1
167	.01.,.0086.,.0073.,.0056.,.0081.,.0063.,.0088.,.0046.,.0034.,.0034.,.0033.,.0023.,.0018,
168	.0013.,.0019.,.0004.,.00065.,.00053.,.00044.,.00037
169	2,1
170	.05.,.05.,.05.,.05.,.05.,.05.,.07.,.08.,.08.,.1.,.13.,.15.,.15.,.14.,.13.,.13.,.13.,.13.,.15.,.14

ORIGINAL PAGE IS
OF POOR QUALITY

171	3,1
172	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
173	4,1
174	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
175	5,1
176	.05,.05,.05,.05,.05,.05,.07,.08,.08,.1,.13,.15,.15,.14,.13,.13,.13,.13,.15,.14
177	1 V.
178	1,1
179	.032,.025,.03,.016,.0125,.01,.008,.0063,.005,.004,.0032,.0025,.002,.0016,
180	.0013,.001,.0008,.00063,.00050,.0004
181	2,1
182	.032,.025,.03,.016,.0125,.01,.008,.0063,.005,.004,.0032,.0025,.002,.0016,
183	.0013,.001,.0008,.00063,.00050,.0004
184	3,0
185	4,1
186	.064,.05,.06,.032,.025,.02,.016,.0126,.01,.008,.0064,.005,.004,.0032,
187	.0026,.002,.0016,.00126,.001,.0008
188	1 W.
189	1,1
190	105,.109,.113,.115,.119,.121,.119,.115,.114,.117,.122,.126,.124,.120,.121,.120.,
191	117,.114,.115,.115.
192	2,1
193	105,.109,.113,.115,.119,.121,.119,.115,.114,.117,.122,.126,.124,.120,.121,.120.,
194	117,.114,.115,.115.
195	3,1
196	105,.109,.113,.115,.119,.121,.119,.115,.114,.117,.122,.126,.124,.120,.121,.120.,
197	117,.114,.115,.115.
198	4,1
199	110,.111,.115,.120,.121,.124,.126,.126,.125,.128,.126,.126,.125,.124,.123,.120.,
200	119,.118,.118,.113.
201	1 X.
202	1,2
203	.0258,.93,.05,.27
204	2,2
205	.0258,.93,.05,.27
206	3,0
207	4,2
208	.0258,.93,.05,.27
209	1 Y.
210	31.5,40.,50.,63.,80.,100.,125.,160.,200.,250.,315.,400.,500.,630.,800.,
211	1000.,1250.,1600.,2000.,2500.
212	0 Z.

ABRPT PRINTS